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Stennis Space Center, MS 39529-5004

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Software Test Description for the Navy Standard Surf Model Version 3.2

THEODORE R. METTLACH
MARSHALL D. EARLE

Neptune Sciences, Inc.
Slidell, Louisiana

Y. LARRY HSU

Ocean Dynamics and Prediction Branch
Oceanography Division

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Theodore Mettlach,* Marshall Earle,* and Y. Larry Hsu

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*Neptune Sciences, Inc., 40201 Highway 190 East, Slidell, LA 70461

14. ABSTRACT

This Software Test Description (STD) is written for the updated Navy Standard Surf Model, Version 3.2, or SURF 3.2, submitted to the Oceanographic and Atmospheric Master Library (OAML). This STD provides the user with procedures, input, and output files to verify the installation of the model.

15. SUBJECT TERMS

STD; OAML; Navy Standard Surf Model; Surf

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SOFTWARE TEST DESCRIPTION FOR THE NAVY STANDARD SURF MODEL VERSION 3.2

1. SCOPE

1.1 Identification

This Software Test Description (STD), prepared for the Oceanographic and Atmospheric Master Library (OAML), provides a variety of test case input and output files to verify the installation of the Navy Standard Surf Model, version 3.2, or SURF 3.2. SURF 3.2 will be called SURF hereafter.

1.2 Document Overview

This STD provides the user with a procedure to verify the installation of the SURF model. If contains a description of how to execute SURF using a test set of four cases. The user should compare model output from the test cases with the expected output provided within the STD for verification of the model installation.

The selected test cases exercise the subroutine components, but not necessarily all individual lines of code in each component. All the test cases selected contain acceptable values for all input fields, thus no error checking statements were exercised. A description of all the error messages is provided in Appendix A.

Manuscript approved October 11, 2002.

2. REFERENCED DOCUMENTS

Earle, M. D., Surf Forecasting Software Users Manual, Naval Research Laboratory (Formerly Naval Ocean Research and Development Activity) Technical Report 352, 194 pp., 1988.

Earle, M. D., Surf Forecasting Software Scientific Reference Manual, Naval Research Laboratory (Formerly Naval Ocean Research and Development Activity) Technical Note 351, 261 pp., 1989.

Earle, M. D., Surf Forecasting Software Improvements, MEC Systems Corp. (now Neptune Sciences, Inc.). Report for Naval Research Laboratory (Formerly Naval Oceanographic and Atmospheric Research Laboratory), 31 pp., 1991.

Hsu, Y. L, T. R. Mettlach, and M. D. Earle, Improvement and Validation of the Navy Longshore Current Model, NRL Formal Report, NRL/FR/7320-00-9927, 41 pp., 2000.

Hsu, Y. L., T. R. Mettlach and M. D. Earle, Validation Test Report for the Navy Standard Surf Model, NRL Formal Report, NRL/FR/7322-02-10008, 28 pp., 2002.

Osiecki, D., L. N. Migues, M. D. Earle and Y. L. Hsu, Software Test Description for the for the Oceanographic and Atmospheric Master Library SURF 3.1 Forecasting Program, NRL Memorandum Report, NRL/MR/7322-00-8252, 91 pp., 2000.

3. TEST PREPARATIONS

SURF is executed by (1) command line input or (2) prompted input. Command line input is as follows:

```
surf32.exe < filename.in
```

If no command line input file is given; that is, if SURF is run with `surf32.exe` alone and with no re-directed input file, then the user will be prompted for an input filename.

If the executable and the input files are not located in the same directory the user can execute SURF from the directory where the input file resides if the path to the executable is given. For example in a DOS environment:

```
C:/models/surf/surf32.exe < filename.in
```

SURF has been compiled and run successfully on the following systems:

1. Fugitsu Lifebook E300 laptop computer; Pentium II microprocessor, 288 MHz; Windows 95 4.00 950C; Microsoft Developer Studio 97, Visual FORTRAN 5.0.
2. Dell DIM4300S desktop computer, Pentium 4 microprocessor, 1.60 GHz, Windows 2000 5.00.2195; Microsoft Developer Studio 97, Visual FORTRAN 5.0.
3. Dell Dimension 4100, Pentium 4 microprocessor, Windows ME 4.9.3000; Microsoft Developer Studio 97, Visual FORTRAN 5.0.
4. Sun Ultra5 workstation; Sparc microprocessor, SunOS 5.8; Sun Workshop FORTRAN compiler, version 5.0
5. Generic desktop computer; i586 processor, 450 MHz; Mandake 8.0, kernel 2.4.3.20 mdk; gnu freeware g77 FORTRAN compiler

SURF produced virtually identical results from these systems. The user may encounter slight differences in the output values due to the machine tolerances and to rounding. The code has also been modified, so that it can be compiled by a FORTRAN 90 compiler.

Besides the standard input file, there are three other files that can be used to provide additional input information:

(1) Depth profile file
(2) Input directional wave spectrum file
(3) Refraction and shoaling file.

There are two other output files, in addition to the basic output file, that can be optionally produced. The two additional ouput files are the:

(1) Surf parameter profile file
(2) Output directional wave spectrum file

SURF produces output files with the same file name as the input file but with different

extensions. The output file will have extension **.out**. The surf parameter profile file without header information will have extension **.dat**. If the directional wave spectrum output file option is called, then a **.dws** file is produced. The input file should not have these extensions. It is good practice to use the extension **.in** for all basic input files, **.dep** for input depth profiles, **.spe** for input spectrum files and **.ref** for input refraction and shoaling files. The above file extensions are used in this report.

4. TEST DESCRIPTIONS

This section describes the four test cases for checking the SURF output. The first case uses an internally generated beach profile based on the sediment type and simple wave input. The second case uses a user provided beach profile and simple wave input. The third case uses an external directional wave spectrum as wave input. Wave refraction from wave input depth to the starting point of surf computation is performed by straight coast refraction. The fourth case is similar to case three except that a wave refraction and shoaling file is used instead of straight coast refraction. A more detailed explanation of model options is presented in section 5.1.5.

The subroutines called in each test case are listed in Table 1. None of the test cases herein calls subroutine `abort`, which is called when errors arise.

Table 1. Subroutines of SURF called by case

Routine Called	case 1	Case 2	case 3	Case 4
1. ABORT.F				
2. BALANCEQ.F	X	X	X	X
3. C_FINE.F		X	X	X
4. C_GAMMA.F	X	X	X	X
5. C_in_dep.f		X	X	X
6. C_REGRID.F		X	X	X
7. C_un.f		X	X	X
8. CALC_HB3.F	X	X	X	X
9. CALCROLL.F	X	X	X	X
10. Calcsurf.f	X	X	X	X
11. Depdrvr.f	X	X	X	X
12. Equilprf.f	X			
13. F2.F	X	X	X	X
14. F3.F	X	X	X	X
15. GENSPEC.F	X	X		
16. Get_brk.f	X	X	X	X
17. Get_diss.f	X	X	X	X
18. Get_p.f	X	X	X	X
19. Get_rhs.f	X	X	X	X
20. get_slope.f	X	X	X	X
21. GET_WAVE.F	X	X	X	X
22. grid_frc.FOR				X
23. Gridout.f		X	X	X
24. Gt_p.f	X	X	X	X
25. GT_SIG_H.F	X	X	X	X
26. INITLIZE.F	X	X	X	X
27. Integrat.f	X	X	X	X
28. KLONG.F	X	X	X	X

29. LIN_1.F		X	X	X
30. LIN_2.F		X	X	X
31. LIN_3.F		X	X	X
32. LIN_4.F		X	X	X
33. LONG1.F	X	X	X	X
34. Main_wav.f	X	X	X	X
35. MDSRF1.F	X	X	X	X
36. Mdsrf2.f	X	X	X	X
37. NEW_BRK.F	X	X	X	X
38. Percent.f	X	X	X	X
39. Prt_out1.f		X	X	X
40. Prt_out2.f				
41. PRT_OUT3.F		X	X	X
42. Pt2.f	X	X	X	X
43. Rad_st1.f	X	X	X	X
44. Rad_st2.f	X	X	X	X
45. Readrfrc.f				X
46. Readspec.f			X	X
47. Refrac.f			X	X
48. RN2.F	X	X	X	X
49. S_coeff.f	X	X	X	X
50. S_NOSURF.F	X	X	X	X
51. S_tide.f	X	X	X	X
52. SEAFIT.F		X		
53. SETUP.F	X	X	X	X
54. Shortout.f	X	X	X	X
55. Slf_strt.f		X	X	X
56. Srfsetup.f	X	X	X	X
57. STRFRAC.F		X	X	
58. SUMMARY.F	X	X	X	X
59. Surf.f	X	X	X	X
60. Surfcast.f	X	X	X	X
61. SWLFIT.F	X	X		
62. WAVEFIT.F	X	X		
63. WAVENUM.F	X	X	X	X
64. weightfn.f	X	X	X	X
65. zone1.f	X	X	X	X

4.1 Test Case 1

Test case 1 is the simplest of the four cases. No input depth profile or wave data files are used. The model internally generates an equilibrium beach profile based on sediment type, and it internally generates a narrow-banded directional wave spectrum based on input swell parameters of height, period and direction. The input swell direction is from 160 degrees at a depth of 25 ft, and the compass heading to the beach is 0 degrees. With the sign convention in SURF, this case generates a negative longshore current, i.e. moving toward the left flank.

The detailed input parameter description is included in section 5. A simplified key is located below the input information, consisting of 12 lines, of which some may be blank.

4.1.1 Test Case 1 Input File - `case1.in`

```
case1.in
2001010101
case 7 beach

7
0
25


0 0 0 3.0 10.0 160
15 180 1.0
5

Key:
1.  input file name
2.  date-time group YYYYMMDDHH
3.  landing zone name
4.  input depth profile name
5.  equilibrium bottom material
6.  beach heading (Sight Line; degrees CW from N.)
7.  depth at location of input wave parameters (line 10)
    or wave spectrum file (line 8)
8.  input directional wave spectrum file name
9.  input wave refraction file name
10. height of input wind waves (feet)
    period of input wind waves (seconds)
    direction of input wind waves(degrees +CW from N.; energy from)
    height of input swell waves (feet)
    period of input swell waves (seconds)
    direction of input swell waves(degrees +CW from N.; energy from)
11. wind speed (knots)
    wind direction (degrees CW from North [wind from])
    tide (feet)
12. interval of cross shore output profiles  (feet)
```

4.1.2 Test Case 1 Output File - case1.out

```
      *****  *****  Surf Forecast  *****  *****

Navy Standard Surf Model     Version 3.2
Date and Time of Forecast:  01/01/2001   0100
Session Logged to file case1.out
Landing Zone Name           = case 7 beach
Sight Line                  =   0.0 deg
Equilibrium Beach Sediment = medium sand
Wave Input Depth            =  25.0 ft
Sea   Height, Period, Direction =   0.0 ft,  0.0 sec,   0.0  deg
Swell Height, Period, Direction =   3.0 ft, 10.0 sec, 160.0  deg
Wind Speed                  =  10.0 kts
Wind Direction              = 240.0 deg
Tide Level                  =  -1.0 ft


Internally Generated Spectrum Used
Starting Depth              =  24.0 ft
Output Interval             =   5.0 ft
Computational grid spacing =   2.0 ft
Significant Wave Height Offshore =      3.0 ft
Peak Period                      =     10.0 sec
Average wave direction           =    -20.0 deg
Percent of Breaking Waves is less than  5.0 %  at starting depth.

    *****  *****  Coded Surf Forecast Follows  *****  *****
 Significant Breaker Height                    alfa =    3.6 ft
 Maximum Breaker Height                       bravo =    5.5 ft
 Dominant Breaker Period                    charlie =   10.0 sec
 Dominant Breaker Type                        delta = Spilling Surf
 ( 84% Spilling,  16% Plunging,   0% Surging)
 Breaker Angle (toward left flank)             echo =   11.9 deg
 Littoral Current (toward left flank)       foxtrot =    1.5 kts
 Number of Surf Lines                         golf1 =    2.0
 Surf Zone Width                              golf2 =  246.0 ft
 Average Wave Length                                =  120.9 ft
 Wind Speed                                  hotel1 =   10.0 kts
 Wind Direction                              hotel2 =  240.0 deg

 Modified Surf Index =      7.2

   *****  *****  Detailed Surf Output Follows  *****  *****

 Indx   Dist    Water  Sig Brkr  Max Brkr  Prcnt  Brkr   Littoral
      Offshore Depth   Height    Height    Brkng  Angle  Current
        (ft)    (ft)     (ft)      (ft)    waves  (deg)  (kts)

   1   302.4     9.3    3.57      5.46      5.2   -12.7    0.12
   2   297.4     9.1    3.57      5.47      5.5   -12.6    0.07
   3   292.4     9.0    3.57      5.47      5.9   -12.5    0.01
   4   287.4     8.9    3.58      5.47      6.3   -12.4   -0.04
   5   282.4     8.8    3.58      5.47      6.8   -12.3   -0.10
```

6	277.4	8.7	3.58	5.47	7.3	-12.3	-0.15
7	272.4	8.6	3.57	5.47	7.8	-12.2	-0.20
8	267.4	8.5	3.57	5.47	8.4	-12.1	-0.25
9	262.4	8.4	3.57	5.46	9.0	-12.0	-0.30
10	257.4	8.2	3.57	5.46	9.6	-11.9	-0.35
11	252.4	8.1	3.57	5.45	10.3	-11.9	-0.40
12	247.4	8.0	3.56	5.45	11.0	-11.8	-0.45
13	242.4	7.9	3.56	5.44	11.8	-11.7	-0.50
14	237.4	7.8	3.55	5.43	12.7	-11.6	-0.55
15	232.4	7.7	3.54	5.42	13.6	-11.5	-0.60
16	227.4	7.5	3.53	5.41	14.6	-11.4	-0.64
17	222.4	7.4	3.52	5.39	15.7	-11.3	-0.69
18	217.4	7.3	3.51	5.37	16.8	-11.2	-0.74
19	212.4	7.2	3.50	5.35	18.0	-11.2	-0.79
20	207.4	7.0	3.49	5.33	19.3	-11.1	-0.83
21	202.4	6.9	3.47	5.31	20.7	-11.0	-0.88
22	197.4	6.8	3.45	5.28	22.1	-10.9	-0.93
23	192.4	6.7	3.43	5.20	23.7	-10.8	-0.97
24	187.4	6.5	3.41	5.10	25.4	-10.7	-1.02
25	182.4	6.4	3.39	5.00	27.2	-10.6	-1.06
26	177.4	6.3	3.37	4.90	29.1	-10.4	-1.11
27	172.4	6.2	3.34	4.80	31.1	-10.3	-1.15
28	167.4	6.0	3.31	4.70	33.3	-10.2	-1.19
29	162.4	5.9	3.28	4.59	35.6	-10.1	-1.23
30	157.4	5.8	3.25	4.49	38.1	-10.0	-1.27
31	152.4	5.6	3.22	4.38	40.8	-9.9	-1.31
32	147.4	5.5	3.18	4.28	43.6	-9.8	-1.35
33	142.4	5.3	3.14	4.17	46.7	-9.6	-1.38
34	137.4	5.2	3.10	4.06	49.9	-9.6	-1.41
35	132.4	5.1	3.06	3.95	53.2	-9.5	-1.44
36	127.4	4.9	3.02	3.84	56.7	-9.3	-1.46
37	122.4	4.8	2.98	3.72	60.3	-9.2	-1.48
38	117.4	4.6	2.93	3.61	63.9	-9.1	-1.50
39	112.4	4.5	2.89	3.49	67.5	-8.9	-1.51
40	107.4	4.3	2.85	3.38	71.1	-8.8	-1.52
41	102.4	4.2	2.81	3.26	74.5	-8.6	-1.53
42	97.4	4.0	2.77	3.14	77.7	-8.5	-1.52
43	92.4	3.9	2.73	3.01	80.8	-8.3	-1.52
44	87.4	3.7	2.69	2.89	83.7	-8.2	-1.51
45	82.4	3.5	2.64	2.76	86.3	-8.0	-1.49
46	77.4	3.4	2.60	2.63	88.7	-7.8	-1.46
47	72.4	3.2	2.50	2.50	90.9	-7.7	-1.43
48	67.4	3.0	2.36	2.36	92.7	-7.5	-1.39
49	62.4	2.9	2.23	2.23	94.3	-7.3	-1.35
50	57.4	2.7	2.09	2.09	95.7	-7.1	-1.30
51	52.4	2.5	1.94	1.94	96.9	-6.9	-1.24
52	47.4	2.3	1.79	1.79	97.8	-6.6	-1.17
53	42.4	2.1	1.64	1.64	98.5	-6.4	-1.09
54	37.4	1.9	1.48	1.48	99.1	-6.1	-1.00
55	32.4	1.7	1.32	1.32	99.4	-5.8	-0.91
56	27.4	1.5	1.15	1.15	99.7	-5.5	-0.80
57	22.4	1.2	0.97	0.97	99.9	-5.2	-0.68
58	17.4	1.0	0.78	0.78	100.0	-4.8	-0.55
59	12.4	0.7	0.58	0.58	100.0	-4.4	-0.41

4.2 Test case 2

Case 3 uses an external depth file, `profile.dep`. The depth profile is listed in Appendix A. Wave input consists of both wind waves and swell waves. The wave input depth is 100 ft, which is deeper than the deepest depth of the depth profile. Consequently, the straight coast refraction feature is automatically turned on to bring input waves to the start of the profile.

4.2.1 Test Case 2 Input File – `case2.in`

```
case2.in
2002020202
case 2 beach
profile.dep

0
100


1.0 5.0 135 3.0 10.0 225
15 180 1.0
10
```

4.2.2 Test case 2 Detailed Output File – `case2.out`

```
      *****  *****  Surf Forecast  *****  *****

Navy Standard Surf Model     Version 3.2
Date and Time of Forecast:  02/02/2002   0200
Session Logged to file case2.out
Landing Zone Name          = case 2 beach
Sight Line                 =   0.0 deg
Depth Profile File         =  profile.dep
Wave Input Depth           = 100.0 ft
Sea   Height, Period, Direction =   1.0 ft,  5.0 sec, 135.0  deg
Swell Height, Period, Direction =   3.0 ft, 10.0 sec, 225.0  deg
Wind Speed                 =  15.0 kts
Wind Direction             = 180.0 deg
Tide Level                 =   1.0 ft

Straight Coast Wave Refraction Applied
Internally Generated Spectrum Used
Starting Depth             =  48.1 ft
Output Interval            =  10.0 ft
Computational grid spacing =   2.0 ft
Significant Wave Height Offshore =      2.7 ft
Peak Period                      =     10.0 sec
Average wave direction           =     27.1 deg
Percent of Breaking Waves is less than  5.0 %  at starting depth.

    *****  *****  Coded Surf Forecast Follows  *****  *****
 Significant Breaker Height                      alfa =    3.5 ft
 Maximum Breaker Height                         bravo =    5.4 ft
 Dominant Breaker Period                      charlie =   10.0 sec
 Dominant Breaker Type                          delta = Plunging Surf
 ( 24% Spilling,  76% Plunging,   0% Surging)
 Breaker Angle (toward right flank)              echo =   11.7 deg
 Littoral Current (toward right flank)        foxtrot =    0.9 kts
 Number of Surf Lines                           golf1 =    2.7
 Surf Zone Width                                golf2 =  372.0 ft
 Average Wave Length                                  =  137.3 ft
 Wind Speed                                    hotel1 =   15.0 kts
 Wind Direction                                hotel2 =  180.0 deg

 Modified Surf Index =      6.5

   *****  *****  Detailed Surf Output Follows  *****  *****

 Indx   Dist    Water  Sig Brkr  Max Brkr  Prcnt  Brkr   Littoral
      Offshore Depth   Height    Height    Brkng  Angle  Current
        (ft)    (ft)    (ft)      (ft)     waves  (deg)   (kts)

   1   401.7     9.1   3.50      5.36      5.0     12.5    0.00
   2   391.7     8.7   3.52      5.38      6.9     12.2    0.11
   3   381.7     8.2   3.52      5.39      9.4     11.8    0.21
   4   371.7     7.7   3.51      5.37     12.5     11.5    0.31
   5   361.7     7.2   3.48      5.33     17.1     11.1    0.40
   6   351.7     6.8   3.44      5.27     21.1     10.8    0.49
   7   341.7     6.4   3.39      5.03     26.4     10.5    0.56
```

8	331.7	6.3	3.33	4.89	28.0	10.4	0.63
9	321.7	6.2	3.28	4.85	27.0	10.3	0.68
10	311.7	6.0	3.23	4.69	29.3	10.2	0.72
11	301.7	5.9	3.17	4.63	28.9	10.1	0.74
12	291.7	6.0	3.13	4.69	25.3	10.2	0.75
13	281.7	6.1	3.09	4.73	22.4	10.3	0.75
14	271.7	6.2	3.06	4.68	19.0	10.4	0.73
15	261.7	6.3	3.03	4.63	16.1	10.5	0.72
16	251.7	6.6	3.00	4.59	12.2	10.7	0.69
17	241.7	6.9	2.97	4.55	9.5	10.9	0.67
18	231.7	7.1	2.95	4.51	7.5	11.1	0.65
19	221.7	7.3	2.93	4.48	6.4	11.2	0.63
20	211.7	7.4	2.91	4.45	5.6	11.3	0.62
21	201.7	7.6	2.90	4.43	4.9	11.5	0.60
22	191.7	7.6	2.88	4.41	4.6	11.5	0.60
23	181.7	7.7	2.87	4.40	4.3	11.5	0.59
24	171.7	7.8	2.86	4.38	3.9	11.6	0.59
25	161.7	7.9	2.85	4.36	3.5	11.7	0.60
26	151.7	7.9	2.84	4.35	3.5	11.7	0.61
27	141.7	7.9	2.84	4.35	3.6	11.7	0.63
28	131.7	7.7	2.85	4.35	4.0	11.6	0.66
29	121.7	7.4	2.86	4.37	5.3	11.3	0.68
30	111.7	7.0	2.87	4.39	7.4	11.0	0.72
31	101.7	6.5	2.87	4.40	10.4	10.7	0.76
32	91.7	6.0	2.87	4.39	16.2	10.2	0.80
33	81.7	5.3	2.83	4.13	28.6	9.6	0.85
34	71.7	4.6	2.73	3.58	49.7	9.0	0.90
35	61.7	4.2	2.62	3.24	63.0	8.6	0.93
36	51.7	3.8	2.53	2.93	74.8	8.2	0.94
37	41.7	3.0	2.32	2.32	92.9	7.3	0.93
38	31.7	2.3	1.77	1.77	98.4	6.5	0.87
39	21.7	1.5	1.19	1.19	99.9	5.4	0.73
40	11.7	0.8	0.66	0.66	100.0	4.2	0.47

4.3 Test case 3

Case 3 uses `profile.dep` and an external directional wave spectrum file, `case3.spe`, is included in Appendix C. The input wave spectrum depth is 60 ft. Beach heading is 270 degree, toward the west.

4.3.1 Test case 3 Input File – `case3.in`

```
case3.in
2000030303
case3
profile.dep

270
60
case3.spe

0 0 0 0 0 0
15 45 -1
10
```

4.3.2 Test case 3 Detailed Output File – `case3.out`

```
      *****  *****  Surf Forecast  *****  *****

Navy Standard Surf Model     Version 3.2
Date and Time of Forecast:  03/03/2000   0300
Session Logged to file case3.out
Landing Zone Name           = case3
Sight Line                  = 270.0 deg
Depth Profile File          =  profile.dep
Wave Input Depth            =  60.0 ft
Spectrum File               =  case3.spe
Wind Speed                  =  15.0 kts
Wind Direction              =  45.0 deg
Tide Level                  =  -1.0 ft

Straight Coast Wave Refraction Applied
External Source Directional Wave Spectrum Used
Starting Depth              =  46.1 ft
Output Interval             =  10.0 ft
Computational grid spacing =   2.0 ft
Significant Wave Height Offshore =      5.0 ft
Peak Period                      =      5.9 sec
Average wave direction           =     28.0 deg
Percent of Breaking Waves is less than  5.0 %  at starting depth.

    *****  *****  Coded Surf Forecast Follows  *****  *****
 Significant Breaker Height                    alfa =    4.0 ft
 Maximum Breaker Height                       bravo =    6.1 ft
 Dominant Breaker Period                    charlie =    5.9 sec
 Dominant Breaker Type                        delta = Spilling Surf
 ( 88% Spilling,  12% Plunging,   0% Surging)
 Breaker Angle (toward right flank)            echo =   15.6 deg
 Littoral Current (toward right flank)      foxtrot =    3.1 kts
 Number of Surf Lines                         golf1 =    5.6
 Surf Zone Width                              golf2 =  418.0 ft
 Average Wave Length                                =   74.6 ft
 Wind Speed                                  hotel1 =   15.0 kts
 Wind Direction                              hotel2 =   45.0 deg

 Modified Surf Index =     12.1

   *****  *****  Detailed Surf Output Follows  *****  *****

 Indx   Dist    Water  Sig Brkr  Max Brkr  Prcnt  Brkr   Littoral
      Offshore Depth   Height    Height    Brkng  Angle  Current
        (ft)    (ft)    (ft)      (ft)     waves  (deg)  (kts)

   1   909.1    13.0   4.98      7.62      5.0     18.2   -0.16
   2   899.1    12.9   4.96      7.60      5.1     18.1   -0.08
   3   889.1    12.8   4.94      7.56      5.2     18.1    0.00
   4   879.1    12.8   4.92      7.53      5.1     18.0    0.07
   5   869.1    12.8   4.90      7.50      5.0     18.0    0.14
   6   859.1    12.8   4.88      7.47      5.0     18.0    0.21
   7   849.1    12.7   4.87      7.45      4.9     18.0    0.28
   8   839.1    12.7   4.85      7.42      4.9     18.0    0.34
```

9	829.1	12.7	4.83	7.39	4.8	18.0	0.40
10	819.1	12.4	4.81	7.36	5.3	17.8	0.45
11	809.1	12.4	4.79	7.33	5.1	17.8	0.51
12	799.1	12.5	4.77	7.30	4.9	17.9	0.56
13	789.1	12.3	4.75	7.27	5.2	17.8	0.61
14	779.1	12.3	4.73	7.24	5.1	17.7	0.66
15	769.1	12.3	4.71	7.21	4.9	17.8	0.71
16	759.1	12.1	4.69	7.18	5.3	17.6	0.75
17	749.1	12.0	4.67	7.15	5.4	17.6	0.79
18	739.1	11.9	4.65	7.12	5.6	17.5	0.84
19	729.1	11.8	4.63	7.08	5.7	17.4	0.88
20	719.1	11.8	4.61	7.05	5.6	17.4	0.92
21	709.1	11.7	4.59	7.02	5.6	17.4	0.95
22	699.1	11.6	4.57	6.99	5.8	17.3	0.99
23	689.1	11.4	4.54	6.95	6.3	17.1	1.03
24	679.1	11.5	4.52	6.92	5.8	17.2	1.06
25	669.1	11.4	4.50	6.89	6.0	17.2	1.09
26	659.1	11.3	4.48	6.85	6.1	17.1	1.12
27	649.1	11.2	4.46	6.82	6.1	17.0	1.16
28	639.1	11.1	4.44	6.79	6.2	17.0	1.19
29	629.1	11.0	4.41	6.75	6.3	16.9	1.22
30	619.1	10.9	4.39	6.72	6.4	17.0	1.25
31	609.1	11.4	4.37	6.69	4.9	17.2	1.28
32	599.1	11.3	4.35	6.66	5.1	17.1	1.31
33	589.1	11.2	4.34	6.64	5.2	17.1	1.34
34	579.1	11.1	4.32	6.61	5.3	17.0	1.37
35	569.1	11.1	4.30	6.58	5.4	17.0	1.41
36	559.1	11.0	4.28	6.55	5.4	16.9	1.44
37	549.1	11.0	4.26	6.52	5.4	16.9	1.48
38	539.1	10.9	4.25	6.50	5.3	16.9	1.52
39	529.1	10.9	4.23	6.47	5.3	16.9	1.57
40	519.1	10.9	4.21	6.44	5.3	16.8	1.61
41	509.1	10.8	4.19	6.41	5.5	16.8	1.66
42	499.1	10.6	4.17	6.39	5.8	16.7	1.71
43	489.1	10.4	4.15	6.35	6.1	16.6	1.77
44	479.1	10.3	4.13	6.32	6.3	16.5	1.83
45	469.1	10.1	4.11	6.29	6.8	16.3	1.89
46	459.1	10.0	4.09	6.25	7.1	16.2	1.95
47	449.1	9.8	4.06	6.21	7.6	16.1	2.02
48	439.1	9.5	4.03	6.17	8.4	15.9	2.10
49	429.1	9.3	4.00	6.12	9.4	15.7	2.18
50	419.1	8.9	3.96	6.05	11.0	15.4	2.26
51	409.1	8.6	3.91	5.98	12.5	15.2	2.34
52	399.1	8.2	3.85	5.90	14.5	14.9	2.43
53	389.1	7.9	3.79	5.80	16.8	14.6	2.53
54	379.1	7.4	3.71	5.67	20.5	14.2	2.62
55	369.1	6.9	3.61	5.42	25.0	13.8	2.72
56	359.1	6.5	3.50	5.07	30.0	13.4	2.81
57	349.1	6.0	3.36	4.66	37.5	12.9	2.89
58	339.1	5.5	3.21	4.27	46.2	12.4	2.97
59	329.1	5.1	3.06	3.95	53.2	12.0	3.03
60	319.1	4.7	2.91	3.65	59.7	11.6	3.05
61	309.1	4.3	2.75	3.37	65.0	11.2	3.04
62	299.1	4.2	2.65	3.31	60.1	11.2	2.98
63	289.1	4.2	2.55	3.24	56.8	11.1	2.88
64	279.1	4.0	2.44	3.09	58.0	10.9	2.74

65	269.1	4.0	2.36	3.08	50.8	10.9	2.57
66	259.1	4.0	2.31	3.15	40.5	11.0	2.38
67	249.1	4.1	2.26	3.21	32.8	11.1	2.18
68	239.1	4.3	2.22	3.32	25.6	11.3	1.98
69	229.1	4.5	2.19	3.35	18.2	11.5	1.79
70	219.1	4.7	2.16	3.31	13.3	11.8	1.61
71	209.1	5.0	2.14	3.27	9.0	12.1	1.45
72	199.1	5.2	2.12	3.25	7.2	12.3	1.31
73	189.1	5.4	2.10	3.22	5.6	12.5	1.18
74	179.1	5.4	2.09	3.20	5.1	12.6	1.07
75	169.1	5.6	2.08	3.18	4.1	12.7	0.98
76	159.1	5.7	2.07	3.17	3.9	12.8	0.91
77	149.1	5.7	2.06	3.15	3.5	12.9	0.84
78	139.1	5.9	2.05	3.14	3.1	13.0	0.80
79	129.1	6.0	2.04	3.12	2.7	13.1	0.76
80	119.1	5.9	2.04	3.12	2.8	13.1	0.74
81	109.1	5.8	2.04	3.12	3.1	13.0	0.73
82	99.1	5.6	2.05	3.13	3.9	12.8	0.73
83	89.1	5.2	2.06	3.14	5.9	12.3	0.75
84	79.1	4.8	2.06	3.15	9.2	11.9	0.78
85	69.1	4.4	2.05	3.14	14.8	11.4	0.82
86	59.1	3.7	2.01	2.88	32.1	10.6	0.87
87	49.1	3.0	1.91	2.37	63.1	9.8	0.92
88	39.1	2.4	1.77	1.86	85.3	8.9	0.94
89	29.1	2.0	1.59	1.59	91.2	8.3	0.91
90	19.1	1.5	1.18	1.18	97.8	7.4	0.80
91	9.1	0.7	0.55	0.55	100.0	5.8	0.53

4.4 Test case 4

Test case 4 is the most complicated of the four cases. It uses a directional wave spectrum file, `case4.spe` (Appendix D) and a refraction and shoaling file, `case4.ref` (Appendix E). For this test case, the transformation coefficients are computed for a simple flat, or planar beach. This choice is for simplicity in verifying the computation in SURF. In practice, refraction and shoaling file is used only when one deals with a complicated bathymetry.

4.4.1 Test case 4 Input File – `case4.in`

```
case4.in
2000040404
case4
profile.dep

315
15
case4.spe
case4.ref


20 220 5.2
5
```

4.4.2 Test case 4 Detailed Output File – `case4.out`

```
      *****  *****  Surf Forecast  *****  *****

Navy Standard Surf Model     Version 3.2
Date and Time of Forecast:  04/04/2000   0400
Session Logged to file case4.out
Landing Zone Name           = case4
Sight Line                  = 315.0 deg
Depth Profile File          =  profile.dep
Wave Input Depth            =  15.0 ft
Spectrum File               =  case4.spe
Wind Speed                  =  20.0 kts
Wind Direction              = 220.0 deg
Tide Level                  =   5.2 ft

Wave Refraction File Applied  = case4.ref
External Source Directional Wave Spectrum Used
Starting Depth              =  20.2 ft
Output Interval             =   5.0 ft
Computational grid spacing  =   2.0 ft
Significant Wave Height Offshore =      4.6 ft
Peak Period                 =      5.4 sec
Average wave direction      =    -15.8 deg
Percent of Breaking Waves is less than  5.0 %  at starting depth.

    *****  *****  Coded Surf Forecast Follows  *****  *****
 Significant Breaker Height                    alfa =    4.0 ft
 Maximum Breaker Height                       bravo =    6.1 ft
 Dominant Breaker Period                    charlie =    5.4 sec
 Dominant Breaker Type                        delta = Spilling Surf
 ( 72% Spilling,  28% Plunging,   0% Surging)
 Breaker Angle (toward left flank)             echo =   11.5 deg
 Littoral Current (toward left flank)       foxtrot =    1.9 kts
 Number of Surf Lines                         golf1 =    1.5
 Surf Zone Width                              golf2 =  102.0 ft
 Average Wave Length                                =   68.6 ft
 Wind Speed                                  hotel1 =   20.0 kts
 Wind Direction                              hotel2 =  220.0 deg

Modified Surf Index =      9.8

   *****  *****  Detailed Surf Output Follows  *****  *****

Indx   Dist     Water   Sig Brkr   Max Brkr   Prcnt   Brkr    Littoral
     Offshore Depth     Height     Height     Brkng   Angle   Current
       (ft)    (ft)      (ft)       (ft)     waves   (deg)   (kts)

  1   411.1     12.2    4.70       7.19       5.0    -13.1     0.26
  2   406.1     12.0    4.69       7.17       5.5    -13.0     0.22
  3   401.1     11.8    4.67       7.15       6.0    -12.9     0.17
  4   396.1     11.5    4.65       7.12       6.7    -12.8     0.13
  5   391.1     11.3    4.63       7.09       7.1    -12.7     0.09
  6   386.1     11.1    4.61       7.06       7.6    -12.6     0.05
  7   381.1     10.9    4.59       7.03       8.1    -12.5     0.02
```

8	376.1	10.7	4.57	6.99	8.7	-12.4	-0.02
9	371.1	10.6	4.54	6.95	9.2	-12.3	-0.06
10	366.1	10.5	4.52	6.92	9.4	-12.3	-0.09
11	361.1	10.4	4.50	6.89	9.3	-12.2	-0.13
12	356.1	10.4	4.49	6.86	9.2	-12.2	-0.16
13	351.1	10.4	4.47	6.83	9.3	-12.2	-0.19
14	346.1	10.3	4.44	6.80	9.5	-12.2	-0.22
15	341.1	10.2	4.42	6.76	9.8	-12.1	-0.25
16	336.1	10.1	4.40	6.73	9.8	-12.1	-0.28
17	331.1	10.1	4.38	6.71	9.5	-12.1	-0.31
18	326.1	10.2	4.37	6.69	9.1	-12.1	-0.33
19	321.1	10.2	4.36	6.66	8.8	-12.1	-0.36
20	316.1	10.3	4.34	6.64	8.5	-12.1	-0.38
21	311.1	10.3	4.33	6.62	8.2	-12.2	-0.40
22	306.1	10.4	4.31	6.60	7.8	-12.2	-0.42
23	301.1	10.4	4.30	6.58	7.4	-12.2	-0.44
24	296.1	10.5	4.29	6.56	7.1	-12.3	-0.46
25	291.1	10.6	4.28	6.55	6.5	-12.3	-0.48
26	286.1	10.8	4.27	6.53	6.0	-12.4	-0.50
27	281.1	10.9	4.26	6.52	5.6	-12.5	-0.52
28	276.1	11.0	4.25	6.51	5.2	-12.6	-0.54
29	271.1	11.1	4.24	6.49	4.8	-12.6	-0.55
30	266.1	11.3	4.24	6.48	4.4	-12.7	-0.57
31	261.1	11.4	4.23	6.47	4.3	-12.7	-0.59
32	256.1	11.4	4.22	6.46	4.1	-12.8	-0.61
33	251.1	11.5	4.21	6.45	3.8	-12.8	-0.63
34	246.1	11.6	4.21	6.43	3.6	-12.8	-0.65
35	241.1	11.6	4.20	6.42	3.6	-12.8	-0.67
36	236.1	11.7	4.19	6.41	3.5	-12.9	-0.68
37	231.1	11.8	4.19	6.40	3.3	-12.9	-0.70
38	226.1	11.8	4.18	6.39	3.2	-12.9	-0.72
39	221.1	11.8	4.17	6.39	3.2	-12.9	-0.75
40	216.1	11.9	4.17	6.38	3.1	-12.9	-0.77
41	211.1	11.9	4.16	6.37	3.0	-13.0	-0.79
42	206.1	12.0	4.16	6.36	2.9	-13.0	-0.81
43	201.1	12.0	4.15	6.35	2.8	-13.0	-0.83
44	196.1	12.1	4.15	6.34	2.7	-13.0	-0.86
45	191.1	12.2	4.14	6.33	2.6	-13.1	-0.88
46	186.1	12.1	4.14	6.33	2.6	-13.1	-0.91
47	181.1	12.1	4.13	6.32	2.6	-13.1	-0.93
48	176.1	12.1	4.13	6.31	2.6	-13.1	-0.96
49	171.1	12.0	4.12	6.31	2.7	-13.0	-0.99
50	166.1	12.0	4.12	6.30	2.8	-13.0	-1.02
51	161.1	11.8	4.11	6.30	2.9	-12.9	-1.05
52	156.1	11.7	4.11	6.29	3.1	-12.9	-1.08
53	151.1	11.5	4.11	6.28	3.4	-12.8	-1.11
54	146.1	11.3	4.10	6.27	3.8	-12.7	-1.14
55	141.1	11.1	4.09	6.26	4.1	-12.6	-1.17
56	136.1	10.8	4.09	6.25	4.5	-12.5	-1.21
57	131.1	10.6	4.08	6.24	5.0	-12.4	-1.24
58	126.1	10.4	4.07	6.22	5.6	-12.2	-1.28
59	121.1	10.0	4.05	6.20	6.7	-12.1	-1.32
60	116.1	9.7	4.03	6.17	7.9	-11.9	-1.35
61	111.1	9.3	4.01	6.13	9.1	-11.7	-1.39
62	106.1	9.0	3.98	6.09	10.8	-11.5	-1.43
63	101.1	8.7	3.94	6.03	12.5	-11.3	-1.47

64	96.1	8.4	3.91	5.98	13.7	-11.2	-1.51
65	91.1	8.3	3.88	5.93	14.4	-11.1	-1.55
66	86.1	8.1	3.84	5.88	15.5	-11.0	-1.59
67	81.1	7.8	3.80	5.81	17.5	-10.8	-1.64
68	76.1	7.4	3.74	5.72	21.2	-10.6	-1.68
69	71.1	7.0	3.66	5.47	25.5	-10.3	-1.72
70	66.1	6.7	3.59	5.21	29.5	-10.1	-1.76
71	61.1	6.3	3.49	4.89	35.6	-9.8	-1.80
72	56.1	5.9	3.39	4.60	41.9	-9.6	-1.83
73	51.1	5.6	3.29	4.34	48.0	-9.3	-1.87
74	46.1	5.2	3.19	4.08	54.9	-9.1	-1.89
75	41.1	4.9	3.08	3.81	62.4	-8.8	-1.92
76	36.1	4.5	2.98	3.54	70.5	-8.6	-1.93
77	31.1	4.1	2.89	3.23	79.6	-8.2	-1.93
78	26.1	3.7	2.82	2.85	88.6	-7.8	-1.91
79	21.1	3.1	2.39	2.39	95.6	-7.2	-1.88
80	16.1	2.3	1.81	1.81	99.0	-6.4	-1.80
81	11.1	1.5	1.14	1.14	100.0	-5.3	-1.63
82	6.1	0.8	0.61	0.61	100.0	-3.9	-1.23

5. INPUT AND OUTPUT DATA FORMATS

5.1 Input File Formats and model options

This section gives the formats for the files read or produced by SURF.

5.1.1 SURF Input File

The SURF input file contains 12 lines. Some of the lines may be blank; some are required. The format for each line of the input file is al follows:

Line	Description	Type	Units	Range
1	Input File Name	Char*40	-----	-----

The entry in line 1 must be the exact name of the input file. The first character of the file name must be in column 1. The file name is limited to 40 characters.

Line	Description	Type	Units	Range
2	Date and Time YYYYMMDDHH	Char*10	-----	-----

Line 2 is date-time information in the form YYYYMMDDHH. SURF simply reads this line and prints it out in the output file.

Line	Description	Type	Units	Range
3	Landing Zone Name	Char*40	-----	-----

Line 3 is a description of the beach. The string in line 3 cannot be longer than 40 characters or the string will be truncated. This line can be blank, but no information to identify the beach will appear in the output file.

Line	Description	Type	Units	Range
4	Input Depth Profile File Name	Char*40	-----	-----

Line 4 is the name of the input depth profile. The depth profile file name is limited to 40 characters.

Line	Description	Type	Units	Range
5	Sediment Type	Integer	-----	1-10

An entry in line 5 must be given if no depth profile file is included in line 4. If a depth profile is specified in line 4, this line should be left as blank. Allowable entries for bottom composition are as follows

```
1 = Boulders
2 = Cobble
3 = Pebbles
4 = Granules
5 = Very Coarse Sand
6 = Coarse Sand
7 = Medium Sand
```

```
8 = Fine Sand
9 = Very Fine Sand
10 = Silt
```

Line	Description	Type	Units	Range
6	Compass Heading Towards Beach	Real	Degrees	0-359

The compass heading toward the beach is the direction from sea to beach, perpendicular to the beach. Some examples of beach orientation are shown in Fig. 1, part (a).

Line	Description	Type	Units	Range
7	Wave Input Depth	Real	Feet	> 0

Line 7 is the depth in feet at the location of the input waves. The input waves can be in two formats:

(1) a directional wave spectrum from a file given in line 8. Straight coast refraction will be applied if the depth is deeper than available depth profile. If line 9 (wave refraction file) is not blank, this depth corresponds to the output depth where transformation coefficients are applied to offshore input wave. Further illustration is included in the section 5.1.5.

(2) sea and swell parameters in line 10, which are used to generate a synthetic directional wave spectrum within SURF;

Line	Description	Type	Units	Range
8	Input Wave Spectrum File Name	Char*40	-----	-----

Line 8 is the name of the optional input directional wave spectrum file. If a file is entered here then any wave input information line 10 is ignored during SURF execution.

Line	Description	Type	Units	Range
9	Input Wave Refraction File Name	Char*40	-----	-----

Line 9 is the name of the input refraction and shoaling file. It should be noted that the depth at the offshore boundary of the wave refraction computation domain should be the same as offshore wave spectrum input depth. A wave spectrum from line 8 or wave input from line 10 will be modified by the refraction angles and shoaling coefficients in this file. If this line is blank, then simple refraction and shoaling based on a straight coast assumption, i.e. parallel bottom contours, will be applied.

Line	Description	Type	Units	Range
10	Sea Wave Height	Real	Feet	> 0
	Sea Wave Period	Real	Seconds	1 - 30
	Sea Wave Direction	Real	Degrees	0 - 359
	Swell Wave Height	Real	Feet	> 0
	Swell Wave Period	Real	Seconds	1 - 30
	Swell Wave Direction	Real	Degrees	0 - 359

Wave direction is the direction from which waves come in degrees from North. Some examples of wave direction are shown in Fig. 1, part (b). If no directional wave spectrum file is given in line 8 then the model will produce a directional wave spectrum based on the sea and swell parameters given in this line. If a refraction-shoaling file is included then the internally

generated spectrum will be refracted and shoaled to the depth in line 7.

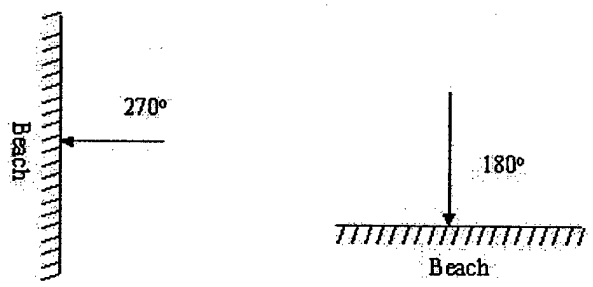
Line	Description	Type	Units	Range
11	Wind Speed	Real	Knots	> 0
	Wind Direction	Real	Degrees	0 - 359
	Tide Elevation	Real	Feet	+ or -

Line 11 gives wind and tide information. Wind direction is the direction from which wind comes in degrees from North.

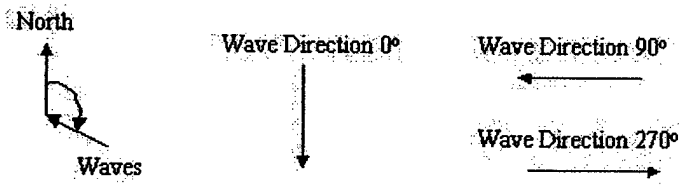
Line	Description	Type	Units	Range
12	Output Grid Spacing	Real	Feet	see note

An entry must be made in line 12. If line 12 is negative then a short output will be produced.

Note: the range of intervals is limited by array sizes and by the surf zone width computed by the model. Error messages will warn the user if the intervals are too small, say less than 2 ft, or too large.



(a) Beach Orientation Definition. Arrows show sight lines from deep water toward the beaches.



(b) Wave Direction Definition. Directions are those from which waves come in degrees relative to North.

Fig. 1 Beach orientation and wave direction definitions.

5.1.2 Depth File

Line	Description	Type	Range
1	Title	Char*80	-----

Line 1 is a simple alphanumeric identifier. The information in this line is not used in SURF.

Line	Description	Type	Range
2	Units for Distance Offshore	Integer	1,2 or 3

Line 2 identifies the units of offshore distances associated with the entries in line 4 and after.

```
1 - Distances in Feet
2 - Distances in Meters
3 - Distances in Yards
```

Line	Description	Type	Range
3	Units for Depth	Integer	1,2 or 3

Line 3 identifies the units of the depths associated with the entries in line 4 and after.

```
1 - Depths in Feet
2 - Depths in Meters
3 - Depths in Fathoms
```

Line	Description	Type	Range
4+	Index number	Integer	1 - 500
	Distance offshore	Real	----
	Depth positive down	Real	----

The depth profile is contained in lines 4 and after. The distance coordinate is zero at the water's edge and increases offshore. The depths associated with each distance are positive down. See Appendix B for a sample input depth profile file.

5.1.3 Directional Wave Spectrum File

The input directional wave spectrum file contains nine preliminary lines of information followed by blocks of data, where each block is associated with a frequency band. The elements of each block are values of spectral energy density in units of meters-squared per hertz per radian.

Lines 1-3 identify the time and location of the spectrum. This information is not used by the model in calculating wave or surf parameters.

Line	Description	Type	Units	Range
1	Longitude	Real	Degrees	-180 - 180
2	Latitude	Real	Degrees	-90 - 90
3	Date - (YYYYMMDD)	Real	-----	----

Line	Description	Type	Units	Range
4	Number of Angles	Integer	-----	1 - 180

Line 4 gives the number of direction bins in the directional wave spectrum. The number in line 4 must equal the number of rows times the number of columns in line 5.

Line	Description	Type	Units	Range
5	Number of Rows	Integer	-----	+ number
	Number of Columns	Integer	-----	+ number

This line gives information for reading each block of spectral energy densities. Each block has the same number of elements, which is the number of rows times the number of columns. Note that the number of elements must be an even number. If the input directional wave spectrum has 24 direction bins then acceptable pairs of row-column combinations are : 24 1; 12 2; 6 4; 3 8; 8 3; 4 6; 2 12; 1 24.

Line	Description	Type	Units	Range
6	Number Frequency Bands	Integer	-----	1 - 50

Line 6 contains the number of frequency bins in the directional wave spectrum.

Line	Description	Type	Units	Range
7	Initial Direction	Real	Degrees	0 - 359

The directional bands associated with the spectrum must increase monotonically. Line 7 gives the initial direction, which will be the smallest angular value in degrees, positive clockwise from North.

Line	Description	Type	Units	Range
8	Width of Direction Bin	Real	Degrees	2 - 180

The number of directional bands is given in line 8.

Note: the width of the direction bins in degrees times the number of direction bins must equal 360 degrees.

Line	Description	Type	Units	Range
9	Direction of Waves	Integer	-----	1 or 2
	1 - Direction waves are coming from			
	2 - Direction waves are going to			

Following the initial nine lines, are blocks of values of spectral energy density in units of meters-squared per hertz per radian. The first line of each block will contain the lower, center and upper frequency of the frequency band associated with that block. The block of values is a rectangular matrix of values in order from left to right being from left to right in direction in increments of the directional bandwidth given in line 8. The block of data must represent directions covering 360 degrees from the initial directional clockwise. In general the format of each block is a follows:

Directional Wave Spectrum - Blocks are repeated for each Frequency Bin

Line	Description	Type	Units	Range
10	Bin Number	Integer	-----	1 - 50
	Lower Limit of Frequency Bin	Real	hertz	> = 0
	Center of Frequency Bin	Real	hertz	> = 0
	Upper Limit of Frequency Bin	Real	hertz	> = 0
11+	Directional Wave Spectrum	Real	m^2/Hz/rad	> = 0

The elements of each block of values comprising the spectral energy densities for a given frequency are in the form of a rectangular matrix of numbers of the number of rows times the number of columns, as in line 5.

5.1.4 Input Wave Refraction and Shoaling Input File

Using the input wave refraction and shoaling input file is an advanced procedure. The refraction and shoaling files used to modify an input directional wave spectrum to a spectrum representative of conditions at the depth given in line 7 of the SURF input file.

Line	Description	Type	Units	Range
1	Header	Character	-----	-----
2	Header	Character	-----	-----
3	Input and Output Depths	Real	Feet	-----

Lines 1-3 are strings of identifying text. The information is not used in computation. In line 3, input depth is the offshore boundary depth, and output depth corresponds to the depth where the transformation coefficients are saved, i.e. the spedepth of line 7 of surf input file.

Line	Description	Type	Units	Range
4	Number of Angles	Integer	-----	1 - 180
5	Number of Rows	Integer	-----	+ number
	Number of Columns	Integer	-----	+ number
6	Number of Freq. Bins	Integer	-----	1 - 50
7	Initial Direction	Real	Degrees	0 - 359
8	Width of Direction Bin	Real	Degrees	2 - 180
9	Direction of Waves	Integer	-----	1 or 2
	1 - Direction waves are coming from			
	2 - Direction waves are going to			

Lines 4-9 are similar to those in the input directional wave spectrum file.

Refraction Angles - This section is repeated for each frequency

Line	Description	Type	Units	Range
10	Bin Number	Integer	-----	1 - 50
	Lower Limit of Frequency Bin	Real	Hertz	> = 0
	Center of Frequency Bin	Real	Hertz	> = 0
	Upper Limit of Frequency Bin	Real	Hertz	> = 0
11+	Refraction Angles	Real	Degrees	0 - 359

End of Refraction Angles

The elements of each block of values comprising the refraction angles for a given frequency are in the form of a rectangular matrix with the number of rows and columns in line 5. Pad fields with zeros, if necessary.

Line	Description	Type	Units	Range
Line A+1	Header 1 for Shoaling Coefficients	Char*80	-----	-----
Line A+2	Header 2 for Shoaling Coefficients	Char*80	-----	-----
Line A+3	Header 3 for Shoaling Coefficients	Char*80	-----	-----

The Line A+ numbering above and below denotes information after the block of refraction angles.

Shoaling Coefficients - This section is repeated for each frequency				
Line	**Description**	**Type**	**Units**	**Range**
Line A+4	Bin Number	Integer	-----	1 - 50
	Lower Limit of Freq Bin	Real	Hertz	> = 0
	Center of Freq Bin	Real	Hertz	> = 0
	Upper Limit of Freq Bin	Real	Hertz	> = 0
Line A+5+	Shoaling Coefficients	Real	m^2/m^2	-------
End of Shoaling Coefficients				

The elements of each block of values comprising the shoaling coefficients for a given frequency are in the form of a rectangular matrix of values with the number of rows and columns given in line 5. Pad fields with zeros, if necessary.

Note: The angles and coefficients in this file must be defined over the entire range (0, 360) degrees. A partial sector definition (e.g. 0 to 180 degrees) will cause errors. If the input data are not available over the entire range pad the refraction and direction bins with zeros.

5.1.5 Model Options

This section gives options in SURF that control wave refraction, equilibrium profile option, and the output files.

Wave Refraction Options

In general, the depth profile should cover depths to around 30 ft. If the depth of input waves is deeper than the deepest depth in the profile, i.e. outside of the profile-covered area, two options are available to consider wave refraction to bring the input waves to the edge of the area over which SURF is to operate. If no bathymetry information is available, straight coast refraction, assuming parallel bottom contours, will be used. If bathymetry information available, one can use the wave modeling option where transformation coefficients for refraction and shoaling are computed. This option is generally only used when the bathymetry is complicated.

As illustrated in Fig. 2, straight coast refraction brings the wave input to the edge of the profile-covered area starting point. It should be noted that if spedepth is inside the profile-covered area, then it becomes starting point. Then no additional wave refraction will be applied. The first output point corresponds to a location where the percent of wave breaking has reached 5%. This avoids a long listing of surf output over long stretches of flat, gently sloping bottoms.

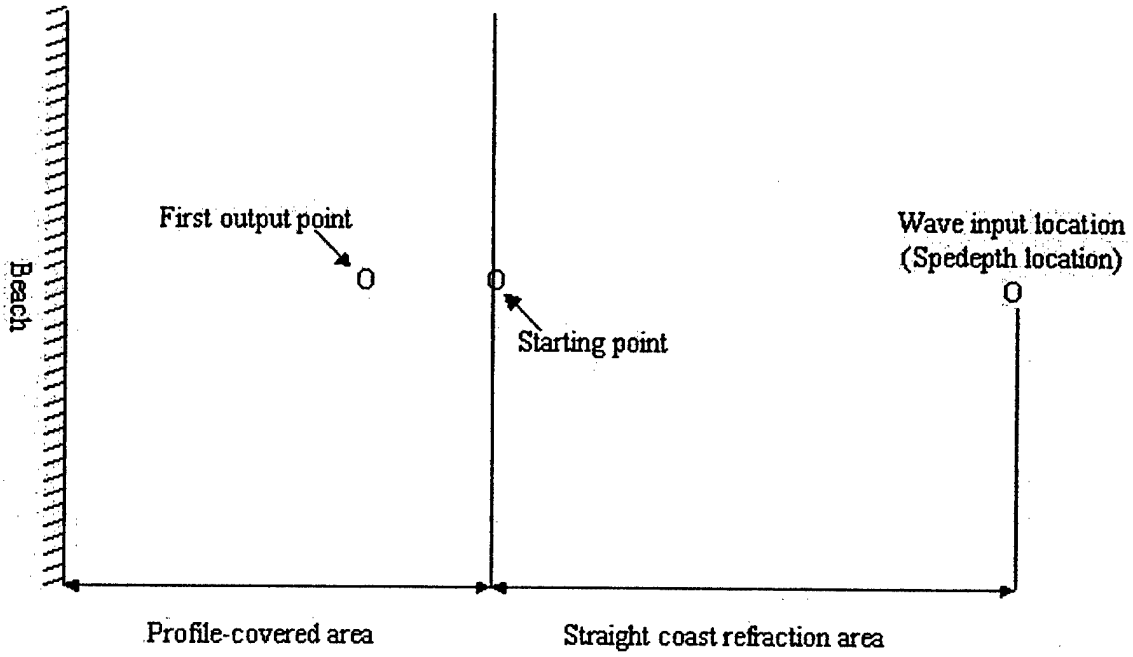


Fig. 2 Illustration of straight coast refraction option. Straight coast refraction brings wave input to the edge of the profile-covered area, i.e. the starting point.

For the wave modeling option, wave models such as REFDIF, STWAVE and SWAN pre-compute needed transformation coefficients for a given bathymetry. Input line 9 specifies the wave refraction file. As illustrated in Fig. 3, the spedepth (input line 7) corresponds to the output depth of the refraction computation. For accuracy, it is requires that the output depth is within the profile-covered area. This is because no additional straight coast refraction will be applied if it falls outside of the profile-covered area. The output depth should not be too shallow (e.g. within the surf zone), because the transformation coefficient approach assumes that no depth induced wave breaking has occurred at the output point. It is recommended that the output depth should be around 25 to 30 ft or deeper depending on the bathymetry and wave conditions.

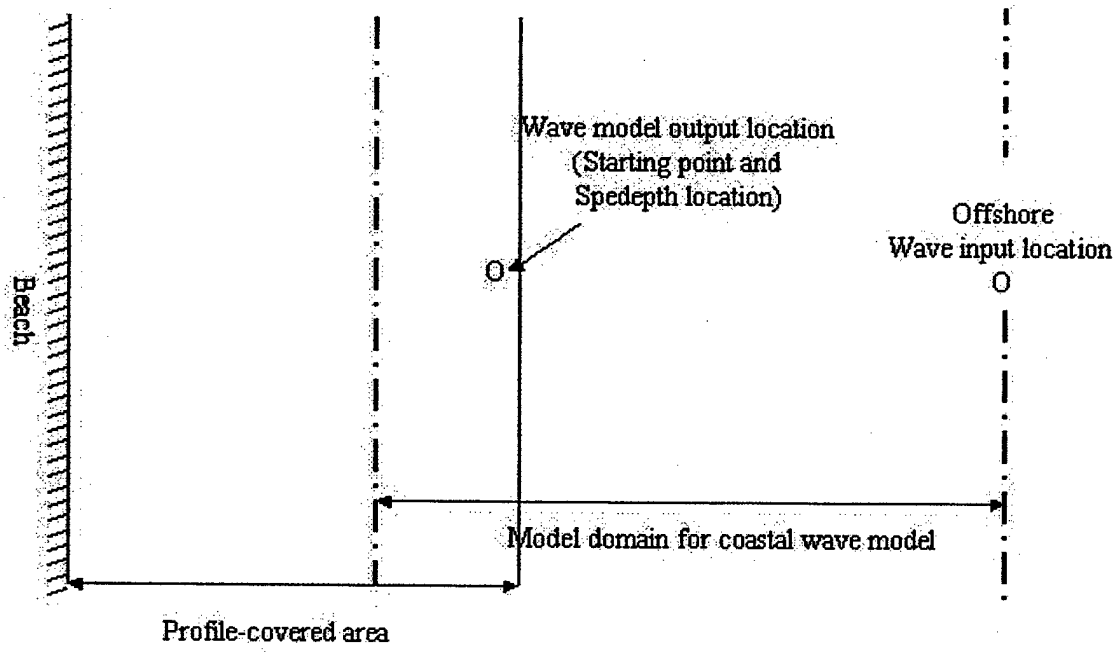


Fig. 3 Illustration of wave modeling option.

The offshore wave input location needs to be at the same depth as the offshore boundary of the refraction file computation.

Equilibrium Profile Option

The equilibrium profile, based on sediment size, is used if a depth profile is not available. In the code, its maximum depth, also the starting depth, is set to 10 m, except for the wave refraction file option in which the maximum depth corresponds to spedepth.

Wave Spectrum Output Option

To obtain an output directional wave spectrum file, place the character "+" in front of the directional wave spectrum file name in line 9 of the basic input file. The ouput file will give the directional wave spectrum associated with the output point, i.e. the spedepth depth. The output spectrum file will have the same file name as the input file name but with the extension `.dws`.

Short Output

In SURF, the user can control the amount of data in the output file. If line 12 contains a zero or a negative number, a short output, without cross shore profiles of surf parameters, will be produced. The short output is similar in format to naval surf observations.

5.2 Output File Formats

5.2.1 Basic Output File

The SURF detailed output has three output sections delineated by lines of asterisks. The first section contains input parameters describing the directional wave spectrum. The second section is the coded surf forecast with variables specific to military surf observations. The final section is the optional detailed surf output, which is comprised of a table of cross shore surf zone parameter. These parameters include cross shore distance, depth, wave height, wave breaking, wave angle and longshore current. The filename generated has the same name as the input file but the extension is `.out`.

Section 1

Line	Description	Type	Units
Line 1	Surf Forecast Header	Character	-----
Line 2	Blank Line	------	-----
Line 3	SURF Model Version	Character	-----
Line 4	Date and Time of Forecast	Character	-----
Line 5	Output File Name Information	Character	-----
Line 6	Landing Zone Name	Character	-----
Line 7	Sight Line Toward Beach	Real	Degrees
Line 8	Depth Profile Name or Beach Sediment Type	Character	-----
Line 9	Wave Input Depth	Real	Feet
Line 10	Spectrum Usage Text	Character	-----
	or		
	Sea Wave Height	Real	Feet
	Sea Period	Real	Seconds
	Sea Direction	Real	Degrees
Line 11	Spectrum File Name	Character	-----
	or		
	Swell Wave Height	Real	Feet
	Swell Period	Real	Seconds
	Swell Direction	Real	Degrees
Line 12	Wind Speed	Real	Knots
Line 13	Wind Direction	Real	Degrees
Line 14	Tide Level	Real	Feet
Line 15	Blank Line	Character	-----
Line 16	Wave Refraction Option	Character	-----
Line 17	Starting Depth	Real	Feet
Line 18	Output Interval	Real	Feet
Line 19	Computational grid Spacing	Real	Feet
Line 20	Input Spectrum Type	Character	-----
Line 21	Significant Wave Height Offshore	Real	Feet
Line 22	Wave Peak Period	Real	Seconds
line 23	Average Wave Direction	Real	Degrees
line 24	Percent Breaking Waves at Starting Depth	Real	Percent

It should be noted that starting depth on line 17 is the depth after offshore waves have brought to the edge of the profile-covered area through either straight coast refraction or refraction file

computation. This depth depends on the depth profile, tide and wave input (spedepth) location.

Section 2

Line	Description	Type	Units
Line 1	Code Surf Forecast	Character	-----
Line 2	Significant Breaker Height	Real	Feet
Line 3	Maximum Breaker Height	Real	Feet
Line 4	Dominant Breaker Period	Real	Seconds
Line 5	Dominant Breaker Type	Character	-----
Line 6	Breaker Percentages	Character	Percent
Line 7	Breaker Angle	Real	Degrees
Line 8	Littoral Current	Real	Knots
Line 9	Number of Surf Lines	Real	-----
Line 10	Surf Zone Width	Real	Feet
Line 11	Wind Speed	Real	Knots
Line 12	Average wave length	Real	Feet
Line 13	Wind Direction	Real	Degrees
Line 14	Blank Line	Character	-----
Line 15	Modified Surf Index	Real	-----

Section 3

Line	Description	Type	Units
Line 1	Blank Line	-----	-----
Line 2	Heading - Detailed Surf Output	Character	-----
Line 3	Blank Line	Character	-----
Line 4	Text Heading Line	Character	-----
Line 5	Text Heading Line	Character	-----
Line 6	Text Heading Line - Units	Character	-----
Line 7	Blank Line	Character	-----
Line 8-EOF	Index Number	Integer	-----
	Distance Offshore	Real	Feet
	Water Depth	Real	Feet
	Significant Breaker Height	Real	Feet
	Maximum Breaker Height	Real	Feet
	Percent Breaking Waves	Real	Percent
	Breaker Angle	Real	Degrees
	Littoral Current	Real	Knots

The first output point in line 8 in section 3 corresponds to a point where percent of wave breaking has reached 5%.

5.2.2 Data Only Output File

The data only output file contains the same information in the same format as the section 3 of the detailed model output, except the file does not contain header information. It is useful in graphic applications.

5.2.3 Shallow Water Directional Wave Spectrum

The shallow water directional wave spectrum output file is created when the first character of

line 6 in the basic input file is a "+". This file has the same file name as the input file except that the file extension will be .dws. The first row contains the center frequencies of the directional wave energy spectrum. The first column defines the wave directions of the directional wave energy spectrum. The remaining matrix elements comprise the directional wave energy spectrum.

	Description	Type	Units	Range
Row 1	Frequency Bins	Real	hertz	0 - 0.5
Column 1	Wave Direction	Real	degrees	0 - 359
Other elements	Spectral Energy Density	Real	$m^2/(Hz\text{-}rad)$	0 - 999

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APPENDICES

Appendix A. Error Message Descriptions

Error Message	Subroutine Generating Error	Suggested Solution to Resolve Error
Error 115 - Opening directional wave spectrum file.	`readspec`	Check wave spectrum file name in the input file - line 5. Verify the location of the spectrum file is the same as the input file.
Error 120 - Opening input file.	`srfsetup`	Check the name of the input file typed at the command prompt (`surf32 < fn.in`) or the name typed during execution (Enter `fn.in`).
Error 125 - Opening of input depth file.	`c_in_dep`	Check depth profile file name in the input file - line 4. Verify the location of the depth file is the same as the input file.
Error 130 - Opening refraction file.	`readrfrc`	Check refraction file name in the input file - line 6. Verify the location of the refraction file is the same as the input file.
Error 145 - Input depth profile has more data points than allowed. Check depth profile. Program stopped.	`c_in_dep`	The maximum number of depth points allowed is 500. Modify depth input file to contain only 500 depth values.
Error 165 - No sediment type selected for Equilibrium Profile.	`equilprf`	A Slope/Sediment Type was not set correctly in the input file line 8. The value must be inclusive of 1-10
Error 170 - No surf.	`surf`	Check the heading toward the beach in the input file, line 7 and the spectrum input file. There may be no surf in the area.

Error 180 - Problem gridding to output file. Program stops.	`prt_out1` `prt_out2`	Check that the input depth profile extends to the beach shoreline and that the tide level - line 12 is not too high.
Error 185 - Problem with wave height values.	`new_brk`	Check the input depth profile. The data may need to be smoothed due to unusual slopes. (Hint: too many negative slopes.)
Error 195 - Significant wave height outside surf zone less than 0.5 ft - no further calculations.	`s_nosurf`	Check the heading toward the beach in the input file - line 7.
Error 200 - Surf forecasts are for situations when waves are more important than winds. This is not the case for input waves and winds. Forecasts may not be valid.	`s_coeff`	Check the input wave and wind conditions in the input file - line 11 and line 12.
Error 205 - Water edge not found. Check tide and/or depths. Program stopped.	`s_tide`	The input depth profile must extend to the beach including the addition of a tide, if specified. There must be a depth at either 0.0, an onshore value, or an elevation.
Error 210 - Wave direction not toward the beach - no further calculations.	`rad_st2`	Check the heading toward the beach in the input file, line 7 and/or the directional wave spectrum file.
Error 215 - Wave induced set-up not converging to tolerance.	`setup`	The input depth profile must be smoothed.
Error 220 - Wave induced set-up is not converging. Ending program.	`main_wav`	The input depth profile must be smoothed.

Appendix B. Depth Profile Input File: `profile.dep`

```
profile.dep
2
2
    1   52.82   -6.78
    2   58.78   -6.25
    3   64.26   -6.32
    4   69.86   -4.31
    5   74.61   -3.52
    6   74.77   -3.48
    7   83.95   -2.98
    8   88.08   -3.00
    9   88.67   -2.94
   10   90.04   -2.76
   11   91.49   -2.54
   12   93.60   -2.23
   13   95.42   -2.00
   14   97.00   -1.76
   15   98.52   -1.56
   16   99.81   -1.40
   17  101.13   -1.22
   18  102.35   -1.05
   19  103.63   -0.80
   20  105.16   -0.60
   21  106.74   -0.42
   22  108.29   -0.28
   23  109.89   -0.16
   24  111.23   -0.07
   25  112.80    0.04
   26  114.49    0.15
   27  116.30    0.27
   28  118.43    0.45
   29  120.57    0.59
   30  122.70    0.78
   31  125.02    0.91
   32  127.73    0.99
   33  129.83    1.09
   34  131.83    1.24
   35  134.49    1.41
   36  136.97    1.60
   37  139.77    1.72
   38  142.66    1.84
   39  144.37    1.91
   40  146.31    1.99
   41  148.22    2.05
   42  150.22    2.08
   43  152.12    2.11
   44  153.87    2.11
   45  155.44    2.12
   46  157.17    2.12
   47  158.99    2.09
   48  160.90    2.07
   49  162.82    2.05
   50  164.94    2.03
   51  167.14    2.02
   52  169.25    2.01
   53  171.06    1.96
   54  173.43    1.96
   55  175.39    1.92
   56  177.39    1.88
   57  179.54    1.86
   58  181.34    1.80
   59  183.31    1.74
   60  185.96    1.69
   61  187.96    1.62
   62  190.47    1.59
   63  192.62    1.56
   64  194.59    1.54
   65  196.59    1.53
   66  198.55    1.51
   67  200.65    1.50
   68  202.68    1.52
   69  204.76    1.57
   70  206.79    1.60
   71  208.52    1.60
   72  210.91    1.62
   73  212.80    1.68
```

74	215.18	1.78
75	217.32	1.86
76	219.33	1.93
77	221.39	2.05
78	223.92	2.16
79	225.82	2.27
80	227.84	2.35
81	229.98	2.46
82	231.61	2.53
83	234.49	2.68
84	236.02	2.72
85	237.96	2.80
86	240.43	2.89
87	242.28	2.95
88	244.16	3.01
89	245.98	3.07
90	247.71	3.14
91	249.91	3.20
92	252.00	3.25
93	253.70	3.29
94	255.40	3.33
95	257.36	3.36
96	259.51	3.39
97	261.48	3.43
98	263.23	3.46
99	265.22	3.48
100	267.53	3.51
101	269.60	3.55
102	271.52	3.58
103	273.62	3.60
104	275.18	3.62
104	277.92	3.63
105	279.71	3.64
107	281.30	3.64
108	283.25	3.65
109	285.28	3.65
110	287.04	3.66
111	289.01	3.67
112	291.96	3.69
113	293.63	3.70
114	295.44	3.72
115	297.31	3.74
116	299.12	3.75
116	300.74	3.76
117	302.84	3.80
119	304.59	3.87
120	304.88	3.63
121	312.84	3.70
122	318.85	3.75
123	323.81	3.80
124	325.89	3.76
125	327.82	3.77
126	329.97	3.84
127	331.83	3.87
128	332.04	3.86
129	333.94	3.89
130	334.23	3.87
131	336.07	3.90
132	338.05	3.88
133	340.27	3.91
134	340.41	3.88
135	342.34	3.94
136	344.11	3.93
137	344.35	3.95
138	346.50	3.99
139	349.27	4.01
140	350.29	3.99
141	351.18	4.07
142	353.33	4.08
143	355.33	4.02
144	357.45	4.06
145	358.98	4.06
146	359.58	4.11
147	361.64	4.13
148	363.07	4.08
149	363.78	4.13
150	367.01	4.07
151	368.20	4.17
152	370.31	4.17

153	372.02	4.18
154	372.05	4.17
155	375.84	4.19
156	384.40	4.20
157	386.85	4.20
158	389.42	4.23
159	408.93	4.38
160	413.10	4.34
161	416.18	4.45
162	418.32	4.47
163	424.54	4.50
164	428.78	4.52
165	435.16	4.55
166	460.70	4.70
167	462.83	4.71
168	469.03	4.74
169	473.38	4.79
170	479.75	4.82
171	483.94	4.85
172	501.36	4.97
173	504.48	5.00
174	532.15	5.21
175	534.27	5.23
176	549.29	5.35
177	557.58	5.39
178	564.06	5.45
179	594.71	5.62
180	602.89	5.70
181	613.05	5.80
182	616.98	5.82
183	644.04	6.01
184	648.15	6.04
185	656.26	6.10
186	662.46	6.14
187	671.36	6.19
188	673.48	6.21
189	707.66	6.42
190	714.11	6.47
191	716.10	6.47
192	755.45	6.74
193	757.65	6.75
194	763.54	6.78
195	767.40	6.82
196	769.19	6.83
197	780.98	6.90
198	791.32	6.97
199	824.09	7.19
200	828.11	7.22
201	860.27	7.41
202	862.25	7.44
203	1002.16	8.36
204	1002.68	8.36
205	1002.88	8.35
206	1003.05	8.37
207	1003.18	8.36
208	1003.30	8.36
208	1003.35	8.36
209	1003.51	8.37
210	1003.57	8.37
211	1003.66	8.38
213	1003.73	8.36
214	1003.77	8.37
215	1003.86	8.35
216	1004.05	8.35
217	1004.41	8.36
218	1004.47	8.36
219	1004.56	8.34
220	1004.64	8.34
221	1004.72	8.34
222	1022.16	8.43
223	1023.86	8.46
224	1032.68	8.52
225	1036.47	8.52
226	1042.83	8.57
227	1047.98	8.60
228	1053.20	8.62
229	1056.92	8.65
230	1061.94	8.65
231	1069.48	8.68

232	1073.59	8.71
233	1080.55	8.79
233	1083.86	8.83
234	1089.04	8.86
235	1092.24	8.93
236	1101.07	8.94
238	1104.41	8.98
239	1110.38	9.02
240	1113.92	9.03
241	1122.44	9.08
242	1125.59	9.11
243	1241.46	9.90
244	1244.26	9.90
245	1247.34	9.94
246	1250.04	9.95
247	1258.52	10.03
248	1261.96	10.05
249	1266.64	10.07
250	1273.16	10.11
251	1276.32	10.14
252	1283.62	10.19
253	1287.15	10.23
254	1291.96	10.25
255	1295.57	10.28
256	1302.48	10.32
257	1307.89	10.37
258	1313.57	10.37
259	1316.88	10.39
260	1321.52	10.42
261	1328.57	10.49
262	1328.70	10.52
263	1329.37	10.54
264	1330.13	10.54
265	1331.76	10.55
266	1331.84	10.55
267	1332.04	10.51
268	1332.51	10.54
269	1333.62	10.56
270	1337.66	10.56
271	1342.47	10.59
272	1347.84	10.62
273	1353.39	10.64
274	1358.05	10.67
275	1365.29	10.73
276	1368.71	10.74
277	1373.67	10.80
278	1378.71	10.85
279	1381.93	10.86
280	1388.82	10.88
281	1395.53	10.92
282	1400.01	10.93
283	1403.69	10.95
284	1406.87	10.97
285	1408.99	10.98
286	1410.27	10.99
287	1416.30	11.06
288	1417.86	11.07
289	1424.38	11.09
290	1536.53	11.84
291	1536.69	11.83
292	1536.75	11.82
293	1537.00	11.83
294	1537.46	11.85
295	1537.83	11.84
296	1538.30	11.82
297	1539.05	11.85
298	1539.32	11.86
299	1539.50	11.82
300	1540.83	11.83
301	1542.06	11.87
302	1542.89	11.84
303	1543.35	11.87
304	1543.76	11.88
305	1545.19	11.85
306	1547.01	11.86
307	1548.31	11.90
308	1549.67	11.88
309	1551.80	11.93
310	1554.48	11.91

311	1559.24	11.96
312	1559.76	11.93
313	1561.38	11.99
314	1562.34	11.95
315	1567.00	11.97
316	1570.20	11.99
317	1571.29	11.99
318	1573.85	12.01
319	1576.00	12.02
320	1577.80	12.04
321	1581.80	12.04
322	1584.29	12.06
323	1585.97	12.08
324	1586.62	12.07
325	1592.35	12.11
326	1594.12	12.12
327	1595.71	12.15
328	1600.65	12.15
329	1601.74	12.16
330	1604.95	12.20
331	1607.20	12.19
332	1610.43	12.22
333	1611.50	12.24
334	1615.99	12.25
335	1618.07	12.30
336	1618.93	12.27
337	1623.51	12.33
338	1630.60	12.38
339	1636.42	12.40
340	1641.29	12.41
341	1646.32	12.44
342	1651.77	12.44
343	1657.76	12.48
344	1664.18	12.52
345	1669.31	12.57
346	1672.70	12.60
347	1679.66	12.62
348	1685.90	12.66
349	1688.83	12.68
350	1694.77	12.70
351	1698.06	12.72
352	1703.93	12.76
353	1708.11	12.78
354	1715.02	12.80
355	1722.10	12.83
356	1723.56	12.85
357	1731.83	12.86
358	1735.53	12.89
359	1739.12	12.91
360	1744.17	12.95
361	1751.93	12.96
362	1755.21	13.00
363	1761.11	13.01
364	1764.00	13.04
365	1767.90	13.05
366	1772.53	13.07
367	1778.69	13.08
368	1785.27	13.11
369	1787.61	13.14
370	1793.52	13.16
371	1795.01	13.16
372	1797.97	13.18
373	1800.44	13.19
374	1805.26	13.22
375	1807.55	13.23
376	1811.49	13.25
377	1816.04	13.27
378	1821.94	13.30
379	1827.22	13.33
380	1831.49	13.35
381	1833.13	13.33
382	1838.04	13.35
383	1838.82	13.38
384	1842.09	13.38
385	1844.37	13.40
386	1846.10	13.41
387	1848.77	13.42
388	1852.39	13.44
389	1852.91	13.43

390	1859.81	13.46
391	1864.85	13.49
392	1870.74	13.51
393	1872.46	13.53
394	1881.47	13.53
395	1883.91	13.57
396	1890.65	13.59
397	1894.95	13.61
398	1897.91	13.65
399	1904.44	13.66
400	1908.87	13.67
401	1913.33	13.71
402	1917.35	13.72
403	1922.48	13.74
404	1923.45	13.76
405	1926.13	13.76
406	1926.81	13.76
407	1929.81	13.78
408	1933.65	13.80
409	1935.24	13.81
410	1935.87	13.81
411	1939.41	13.82
412	1942.22	13.84
413	1944.37	13.74
414	1946.34	13.74
415	1949.63	13.86
416	1949.82	13.85
417	1950.02	13.75
417	1953.10	13.75
419	1954.14	13.87
419	1954.80	13.75
421	1956.31	13.77
421	1956.84	13.90
423	1957.34	13.89
423	1958.63	13.78
425	1959.30	13.79
426	1961.15	13.80
427	1962.01	13.90
428	1962.43	13.80
429	1962.88	13.80
430	1962.94	13.91
431	1963.88	13.80
432	1964.33	13.80
433	1965.66	13.92
434	1969.94	13.92
435	1970.03	13.93
436	1972.02	13.94
437	1974.09	13.94
438	1975.01	13.96
439	1976.00	13.96
440	1976.67	13.97
441	1979.49	13.97
442	1980.29	13.98
442	1981.95	13.98
444	1985.26	14.00
444	1988.17	14.01
446	1990.29	14.02
446	1993.15	14.04
448	1996.55	14.04
448	1998.20	14.03
450	2002.78	14.07
451	2006.32	14.07
452	2007.22	14.08
453	2010.06	14.10
454	2011.51	14.10
455	2016.72	14.12
456	2020.25	14.14
457	2021.61	14.13
458	2023.38	14.15
459	2026.68	14.18
460	2028.71	14.18
461	2030.42	14.19
462	2032.57	14.19
463	2033.04	14.19
464	2034.64	14.18
465	2045.63	14.23
466	2048.39	14.22
467	2050.05	14.24
467	2051.87	14.22

```
469 2052.55   14.25
469 2053.70   14.23
471 2058.98   14.28
471 2062.72   14.30
473 2069.36   14.33
473 2075.75   14.35
```

Appendix C. Test case 3 Wave Spectrum File – `case3.spe`

```
  9999
  9999
  9999
 72
 12  6
 25
0.0
  5.0
  1
  1 0.033333 0.033333 0.034960
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  2 0.034960 0.036667 0.038456
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0.3040E-07 0.3455E-07 0.3882E-07 0.4316E-07 0.4750E-07 0.5177E-07
0.5590E-07 0.5983E-07 0.6348E-07 0.6679E-07 0.6971E-07 0.7217E-07
0.7413E-07 0.7557E-07 0.7644E-07 0.7673E-07 0.7644E-07 0.7557E-07
0.7413E-07 0.7217E-07 0.6971E-07 0.6679E-07 0.6348E-07 0.5983E-07
0.5590E-07 0.5177E-07 0.4750E-07 0.4316E-07 0.3882E-07 0.3455E-07
0.3040E-07 0.2642E-07 0.2267E-07 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
11 0.082435 0.086458 0.090678
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1017E-04 0.1185E-04
0.1364E-04 0.1550E-04 0.1742E-04 0.1936E-04 0.2131E-04 0.2323E-04
0.2508E-04 0.2684E-04 0.2848E-04 0.2997E-04 0.3128E-04 0.3238E-04
0.3326E-04 0.3390E-04 0.3429E-04 0.3442E-04 0.3429E-04 0.3390E-04
0.3326E-04 0.3238E-04 0.3128E-04 0.2997E-04 0.2848E-04 0.2684E-04
0.2508E-04 0.2323E-04 0.2131E-04 0.1936E-04 0.1742E-04 0.1550E-04
0.1364E-04 0.1185E-04 0.1017E-04 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
12 0.090678 0.095104 0.099746
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.5989E-03 0.6980E-03
0.8030E-03 0.9126E-03 0.1026E-02 0.1140E-02 0.1255E-02 0.1368E-02
```

0.1477E-02 0.1580E-02 0.1677E-02 0.1764E-02 0.1841E-02 0.1907E-02
0.1958E-02 0.1996E-02 0.2019E-02 0.2027E-02 0.2019E-02 0.1996E-02
0.1958E-02 0.1907E-02 0.1841E-02 0.1764E-02 0.1677E-02 0.1580E-02
0.1477E-02 0.1368E-02 0.1255E-02 0.1140E-02 0.1026E-02 0.9126E-03
0.8030E-03 0.6980E-03 0.5989E-03 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
13 0.099746 0.104614 0.109720
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.8598E-02 0.1002E-01
0.1153E-01 0.1310E-01 0.1472E-01 0.1637E-01 0.1801E-01 0.1963E-01
0.2120E-01 0.2269E-01 0.2407E-01 0.2533E-01 0.2644E-01 0.2737E-01
0.2812E-01 0.2866E-01 0.2899E-01 0.2910E-01 0.2899E-01 0.2866E-01
0.2812E-01 0.2737E-01 0.2644E-01 0.2533E-01 0.2407E-01 0.2269E-01
0.2120E-01 0.1963E-01 0.1801E-01 0.1637E-01 0.1472E-01 0.1310E-01
0.1153E-01 0.1002E-01 0.8598E-02 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
14 0.109720 0.115076 0.120692
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.4636E-01 0.5403E-01
0.6216E-01 0.7064E-01 0.7939E-01 0.8826E-01 0.9713E-01 0.1059E+00
0.1143E+00 0.1223E+00 0.1298E+00 0.1366E+00 0.1425E+00 0.1476E+00
0.1516E+00 0.1545E+00 0.1563E+00 0.1569E+00 0.1563E+00 0.1545E+00
0.1516E+00 0.1476E+00 0.1425E+00 0.1366E+00 0.1298E+00 0.1223E+00
0.1143E+00 0.1059E+00 0.9713E-01 0.8826E-01 0.7939E-01 0.7064E-01
0.6216E-01 0.5403E-01 0.4636E-01 0.0000E+00 0.0000E+00 0.0000E+00
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15 0.120692 0.126583 0.132762
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1270E+00 0.1480E+00
0.1703E+00 0.1935E+00 0.2175E+00 0.2418E+00 0.2661E+00 0.2900E+00
0.3131E+00 0.3351E+00 0.3556E+00 0.3742E+00 0.3905E+00 0.4043E+00
0.4153E+00 0.4233E+00 0.4282E+00 0.4298E+00 0.4282E+00 0.4233E+00
0.4153E+00 0.4043E+00 0.3905E+00 0.3742E+00 0.3556E+00 0.3351E+00
0.3131E+00 0.2900E+00 0.2661E+00 0.2418E+00 0.2175E+00 0.1935E+00
0.1703E+00 0.1480E+00 0.1270E+00 0.0000E+00 0.0000E+00 0.0000E+00
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16 0.132762 0.139242 0.146038
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.2182E+00 0.2543E+00
0.2925E+00 0.3325E+00 0.3736E+00 0.4153E+00 0.4571E+00 0.4982E+00
0.5379E+00 0.5757E+00 0.6109E+00 0.6428E+00 0.6708E+00 0.6945E+00
0.7134E+00 0.7272E+00 0.7356E+00 0.7384E+00 0.7356E+00 0.7272E+00
0.7134E+00 0.6945E+00 0.6708E+00 0.6428E+00 0.6109E+00 0.5757E+00
0.5379E+00 0.4982E+00 0.4571E+00 0.4153E+00 0.3736E+00 0.3325E+00
0.2925E+00 0.2543E+00 0.2182E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
17 0.146038 0.153166 0.160642
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.2719E+00 0.3169E+00
0.3646E+00 0.4144E+00 0.4657E+00 0.5177E+00 0.5697E+00 0.6210E+00
0.6705E+00 0.7176E+00 0.7614E+00 0.8012E+00 0.8361E+00 0.8657E+00
0.8893E+00 0.9064E+00 0.9169E+00 0.9204E+00 0.9169E+00 0.9064E+00
0.8893E+00 0.8657E+00 0.8361E+00 0.8012E+00 0.7614E+00 0.7176E+00
0.6705E+00 0.6210E+00 0.5697E+00 0.5177E+00 0.4657E+00 0.4144E+00
0.3646E+00 0.3169E+00 0.2719E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
18 0.160642 0.168482 0.176706
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.2720E+00 0.3170E+00
0.3647E+00 0.4145E+00 0.4658E+00 0.5178E+00 0.5699E+00 0.6211E+00
0.6707E+00 0.7178E+00 0.7616E+00 0.8014E+00 0.8364E+00 0.8659E+00

0.8895E+00 0.9067E+00 0.9171E+00 0.9206E+00 0.9171E+00 0.9067E+00
0.8895E+00 0.8659E+00 0.8364E+00 0.8014E+00 0.7616E+00 0.7178E+00
0.6707E+00 0.6211E+00 0.5699E+00 0.5178E+00 0.4658E+00 0.4145E+00
0.3647E+00 0.3170E+00 0.2720E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
19 0.176706 0.185331 0.194376
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.2340E+00 0.2727E+00
0.3137E+00 0.3566E+00 0.4007E+00 0.4455E+00 0.4903E+00 0.5343E+00
0.5770E+00 0.6175E+00 0.6552E+00 0.6894E+00 0.7195E+00 0.7449E+00
0.7652E+00 0.7800E+00 0.7890E+00 0.7920E+00 0.7890E+00 0.7800E+00
0.7652E+00 0.7449E+00 0.7195E+00 0.6894E+00 0.6552E+00 0.6175E+00
0.5770E+00 0.5343E+00 0.4903E+00 0.4455E+00 0.4007E+00 0.3566E+00
0.3137E+00 0.2727E+00 0.2340E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
20 0.194376 0.203864 0.213814
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1816E+00 0.2116E+00
0.2435E+00 0.2767E+00 0.3109E+00 0.3457E+00 0.3804E+00 0.4146E+00
0.4477E+00 0.4792E+00 0.5084E+00 0.5350E+00 0.5583E+00 0.5780E+00
0.5938E+00 0.6052E+00 0.6122E+00 0.6145E+00 0.6122E+00 0.6052E+00
0.5938E+00 0.5780E+00 0.5583E+00 0.5350E+00 0.5084E+00 0.4792E+00
0.4477E+00 0.4146E+00 0.3804E+00 0.3457E+00 0.3109E+00 0.2767E+00
0.2435E+00 0.2116E+00 0.1816E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
21 0.213814 0.224250 0.235196
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1313E+00 0.1530E+00
0.1760E+00 0.2001E+00 0.2248E+00 0.2500E+00 0.2751E+00 0.2998E+00
0.3237E+00 0.3465E+00 0.3676E+00 0.3868E+00 0.4037E+00 0.4180E+00
0.4294E+00 0.4376E+00 0.4427E+00 0.4444E+00 0.4427E+00 0.4376E+00
0.4294E+00 0.4180E+00 0.4037E+00 0.3868E+00 0.3676E+00 0.3465E+00
0.3237E+00 0.2998E+00 0.2751E+00 0.2500E+00 0.2248E+00 0.2001E+00
0.1760E+00 0.1530E+00 0.1313E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
22 0.235196 0.246675 0.258715
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.9047E-01 0.1054E+00
0.1213E+00 0.1379E+00 0.1549E+00 0.1722E+00 0.1895E+00 0.2066E+00
0.2231E+00 0.2387E+00 0.2533E+00 0.2665E+00 0.2782E+00 0.2880E+00
0.2958E+00 0.3015E+00 0.3050E+00 0.3062E+00 0.3050E+00 0.3015E+00
0.2958E+00 0.2880E+00 0.2782E+00 0.2665E+00 0.2533E+00 0.2387E+00
0.2231E+00 0.2066E+00 0.1895E+00 0.1722E+00 0.1549E+00 0.1379E+00
0.1213E+00 0.1054E+00 0.9047E-01 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
23 0.258715 0.271343 0.284587
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.6031E-01 0.7029E-01
0.8086E-01 0.9191E-01 0.1033E+00 0.1148E+00 0.1264E+00 0.1377E+00
0.1487E+00 0.1592E+00 0.1689E+00 0.1777E+00 0.1854E+00 0.1920E+00
0.1972E+00 0.2010E+00 0.2033E+00 0.2041E+00 0.2033E+00 0.2010E+00
0.1972E+00 0.1920E+00 0.1854E+00 0.1777E+00 0.1689E+00 0.1592E+00
0.1487E+00 0.1377E+00 0.1264E+00 0.1148E+00 0.1033E+00 0.9191E-01
0.8086E-01 0.7029E-01 0.6031E-01 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
24 0.284587 0.298477 0.313045
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.3931E-01 0.4582E-01
0.5271E-01 0.5991E-01 0.6732E-01 0.7484E-01 0.8236E-01 0.8977E-01
0.9694E-01 0.1037E+00 0.1101E+00 0.1158E+00 0.1209E+00 0.1252E+00
0.1286E+00 0.1310E+00 0.1325E+00 0.1331E+00 0.1325E+00 0.1310E+00

```
0.1286E+00 0.1252E+00 0.1209E+00 0.1158E+00 0.1101E+00 0.1037E+00
0.9694E-01 0.8977E-01 0.8236E-01 0.7484E-01 0.6732E-01 0.5991E-01
0.5271E-01 0.4582E-01 0.3931E-01 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
25 0.313045 0.328325 0.328325
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
```

Appendix D. Test case 4 Wave Spectrum File – `case4.spe`

```
  9999
  9999
  9999
 72
 12  6
 25
0.0
  5.0
  1
  1 0.033333 0.033333 0.034960
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
18 0.160642 0.168482 0.176706
0.0000E+00 0.2055E+00 0.2395E+00 0.2755E+00 0.3131E+00 0.3519E+00
0.3912E+00 0.4305E+00 0.4692E+00 0.5067E+00 0.5422E+00 0.5753E+00
0.6054E+00 0.6318E+00 0.6541E+00 0.6719E+00 0.6849E+00 0.6928E+00

0.6954E+00 0.6928E+00 0.6849E+00 0.6719E+00 0.6541E+00 0.6318E+00
0.6054E+00 0.5753E+00 0.5422E+00 0.5067E+00 0.4692E+00 0.4305E+00
0.3912E+00 0.3519E+00 0.3131E+00 0.2755E+00 0.2395E+00 0.2055E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
19 0.176706 0.185331 0.194376
0.0000E+00 0.2504E+00 0.2918E+00 0.3357E+00 0.3816E+00 0.4288E+00
0.4767E+00 0.5246E+00 0.5717E+00 0.6174E+00 0.6608E+00 0.7011E+00
0.7377E+00 0.7699E+00 0.7971E+00 0.8188E+00 0.8346E+00 0.8442E+00
0.8474E+00 0.8442E+00 0.8346E+00 0.8188E+00 0.7971E+00 0.7699E+00
0.7377E+00 0.7011E+00 0.6608E+00 0.6174E+00 0.5717E+00 0.5246E+00
0.4767E+00 0.4288E+00 0.3816E+00 0.3357E+00 0.2918E+00 0.2504E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
20 0.194376 0.203864 0.213814
0.0000E+00 0.2466E+00 0.2874E+00 0.3306E+00 0.3758E+00 0.4223E+00
0.4695E+00 0.5166E+00 0.5631E+00 0.6080E+00 0.6508E+00 0.6905E+00
0.7265E+00 0.7582E+00 0.7850E+00 0.8064E+00 0.8220E+00 0.8314E+00
0.8346E+00 0.8314E+00 0.8220E+00 0.8064E+00 0.7850E+00 0.7582E+00
0.7265E+00 0.6905E+00 0.6508E+00 0.6080E+00 0.5631E+00 0.5166E+00
0.4695E+00 0.4223E+00 0.3758E+00 0.3306E+00 0.2874E+00 0.2466E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
21 0.213814 0.224250 0.235196
0.0000E+00 0.2099E+00 0.2446E+00 0.2814E+00 0.3199E+00 0.3594E+00
0.3996E+00 0.4398E+00 0.4793E+00 0.5176E+00 0.5539E+00 0.5877E+00
0.6184E+00 0.6454E+00 0.6682E+00 0.6864E+00 0.6997E+00 0.7077E+00
0.7104E+00 0.7077E+00 0.6997E+00 0.6864E+00 0.6682E+00 0.6454E+00
0.6184E+00 0.5877E+00 0.5539E+00 0.5176E+00 0.4793E+00 0.4398E+00
0.3996E+00 0.3594E+00 0.3199E+00 0.2814E+00 0.2446E+00 0.2099E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
22 0.235196 0.246675 0.258715
0.0000E+00 0.1617E+00 0.1885E+00 0.2168E+00 0.2464E+00 0.2769E+00
0.3078E+00 0.3388E+00 0.3692E+00 0.3987E+00 0.4267E+00 0.4528E+00
0.4764E+00 0.4972E+00 0.5147E+00 0.5288E+00 0.5390E+00 0.5452E+00
0.5473E+00 0.5452E+00 0.5390E+00 0.5288E+00 0.5147E+00 0.4972E+00
0.4764E+00 0.4528E+00 0.4267E+00 0.3987E+00 0.3692E+00 0.3388E+00
0.3078E+00 0.2769E+00 0.2464E+00 0.2168E+00 0.1885E+00 0.1617E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
23 0.258715 0.271343 0.284587
0.0000E+00 0.1163E+00 0.1356E+00 0.1560E+00 0.1773E+00 0.1992E+00
0.2215E+00 0.2437E+00 0.2657E+00 0.2869E+00 0.3070E+00 0.3258E+00
0.3428E+00 0.3577E+00 0.3704E+00 0.3804E+00 0.3878E+00 0.3923E+00
0.3938E+00 0.3923E+00 0.3878E+00 0.3804E+00 0.3704E+00 0.3577E+00
0.3428E+00 0.3258E+00 0.3070E+00 0.2869E+00 0.2657E+00 0.2437E+00
0.2215E+00 0.1992E+00 0.1773E+00 0.1560E+00 0.1356E+00 0.1163E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
24 0.284587 0.298477 0.313045
0.0000E+00 0.7989E-01 0.9311E-01 0.1071E+00 0.1217E+00 0.1368E+00
0.1521E+00 0.1674E+00 0.1824E+00 0.1970E+00 0.2108E+00 0.2237E+00
0.2354E+00 0.2456E+00 0.2543E+00 0.2613E+00 0.2663E+00 0.2694E+00
0.2704E+00 0.2694E+00 0.2663E+00 0.2613E+00 0.2543E+00 0.2456E+00

```
0.2354E+00 0.2237E+00 0.2108E+00 0.1970E+00 0.1824E+00 0.1674E+00
0.1521E+00 0.1368E+00 0.1217E+00 0.1071E+00 0.9311E-01 0.7989E-01
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
25 0.313045 0.328325 0.328325
0.0000E+00 0.7889E-07 0.9194E-07 0.1058E-06 0.1202E-06 0.1351E-06
0.1502E-06 0.1653E-06 0.1801E-06 0.1945E-06 0.2082E-06 0.2209E-06
0.2324E-06 0.2425E-06 0.2511E-06 0.2580E-06 0.2629E-06 0.2660E-06
0.2670E-06 0.2660E-06 0.2629E-06 0.2580E-06 0.2511E-06 0.2425E-06
0.2324E-06 0.2209E-06 0.2082E-06 0.1945E-06 0.1801E-06 0.1653E-06
0.1502E-06 0.1351E-06 0.1202E-06 0.1058E-06 0.9194E-07 0.7889E-07
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
```

Appendix E. Test case 4 Input Refraction File – `case4.ref`

```
Header Information
Header Information
99.99 99.99
72
 6 12
18
0.00
5.00
1
         1  5.5000000E-02  5.9999999E-02  6.4999998E-02
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  119.39  119.39  119.39  119.39  120.40  121.55  122.79  124.12  125.53  127.01  128.54
130.12  131.73  133.36  135.00  136.64  138.27  139.88  141.46  142.99  144.47  145.88  147.21
148.45  149.60  150.61  150.61  150.61  150.61    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         2  6.4999998E-02  7.0000000E-02  7.5000003E-02
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  116.70  116.70  117.27  118.26  119.37  120.60  121.93  123.36  124.87  126.45  128.09
129.78  131.50  133.24  135.00  136.76  138.50  140.22  141.91  143.55  145.13  146.64  148.07
149.40  150.63  151.74  152.73  153.30  153.30    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         3  7.4999996E-02  7.9999998E-02  8.5000001E-02
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  114.54  115.30  116.21  117.26  118.44  119.75  121.17  122.68  124.28  125.95  127.69
129.48  131.30  133.14  135.00  136.86  138.70  140.52  142.31  144.05  145.72  147.32  148.83
150.25  151.56  152.74  153.79  154.70  155.46    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         4  8.5000001E-02  9.0000004E-02  9.5000006E-02
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  112.75  113.58  114.57  115.72  117.02  118.44  119.99  121.64  123.38  125.19  127.08
129.01  130.99  132.99  135.00  137.01  139.01  140.99  142.92  144.81  146.62  148.36  150.01
151.56  152.98  154.28  155.43  156.42  157.25    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         5  9.4999999E-02  0.1000000      0.1050000
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  110.70  111.62  112.71  113.98  115.40  116.96  118.65  120.45  122.35  124.33  126.39
128.49  130.64  132.81  135.00  137.19  139.36  141.51  143.61  145.67  147.65  149.55  151.35
153.04  154.60  156.02  157.29  158.38  159.30    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         6  0.1050000      0.1100000      0.1150000
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  108.49  109.50  110.71  112.10  113.66  115.37  117.22  119.19  121.26  123.42  125.65
127.94  130.27  132.63  135.00  137.37  139.73  142.06  144.35  146.58  148.74  150.81  152.78
154.63  156.34  157.90  159.29  160.50  161.51    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         7  0.1150000      0.1200000      0.1250000
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  106.20  107.31  108.64  110.17  111.87  113.74  115.76  117.90  120.15  122.49  124.90
127.37  129.89  132.44  135.00  137.56  140.11  142.63  145.10  147.51  149.85  152.10  154.24
156.26  158.13  159.83  161.36  162.69  163.80    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         8  0.1250000      0.1300000      0.1350000
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00  103.87  105.09  106.55  108.21  110.07  112.11  114.29  116.61  119.03  121.56  124.15
126.81  129.52  132.25  135.00  137.75  140.48  143.19  145.85  148.44  150.97  153.39  155.71
157.89  159.93  161.79  163.45  164.91  166.13    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         9  0.1350000      0.1400000      0.1450000
  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
```

0.00	101.55	102.88	104.47	106.28	108.30	110.49	112.85	115.34	117.94	120.65	123.43
126.27	129.15	132.07	135.00	137.93	140.85	143.73	146.57	149.35	152.06	154.66	157.15
159.51	161.70	163.72	165.53	167.12	168.45	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10	0.1450000		0.1500000		0.1550000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	99.24	100.70	102.42	104.38	106.55	108.91	111.44	114.10	116.89	119.76	122.72
125.74	128.80	131.89	135.00	138.11	141.20	144.26	147.28	150.24	153.11	155.90	158.56
161.09	163.45	165.62	167.58	169.30	170.76	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11	0.1550000		0.1600000		0.1650000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	96.96	98.53	100.39	102.51	104.84	107.37	110.07	112.90	115.86	118.91	122.04
125.23	128.46	131.72	135.00	138.28	141.54	144.77	147.96	151.09	154.14	157.10	159.93
162.63	165.16	167.49	169.61	171.47	173.04	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.1650000		0.1700000		0.1750000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	94.70	96.40	98.41	100.68	103.18	105.87	108.74	111.75	114.87	118.09	121.38
124.74	128.14	131.56	135.00	138.44	141.86	145.26	148.62	151.91	155.13	158.25	161.26
164.13	166.82	169.32	171.59	173.60	175.30	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	13	0.1750000		0.1800000		0.1850000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	92.47	94.31	96.47	98.90	101.56	104.43	107.46	110.63	113.92	117.30	120.76
124.27	127.82	131.41	135.00	138.59	142.18	145.73	149.24	152.70	156.08	159.37	162.54
165.57	168.44	171.10	173.53	175.69	177.53	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	14	0.1850000		0.1900000		0.1950000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	90.28	92.27	94.58	97.17	100.00	103.03	106.23	109.57	113.01	116.55	120.16
123.83	127.53	131.26	135.00	138.74	142.47	146.17	149.84	153.45	156.99	160.43	163.77
166.97	170.00	172.83	175.42	177.73	179.72	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	15	0.1950000		0.2000000		0.2250000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	88.14	90.27	92.74	95.50	98.50	101.70	105.06	108.55	112.15	115.84	119.60
123.41	127.25	131.12	135.00	138.88	142.75	146.59	150.40	154.16	157.85	161.45	164.94
168.30	171.50	174.50	177.26	179.73	181.86	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	16	0.2250000		0.2500000		0.2750000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	78.38	81.36	84.69	88.29	92.10	96.07	100.17	104.36	108.62	112.94	117.31
121.70	126.12	130.56	135.00	139.44	143.88	148.30	152.69	157.06	161.38	165.64	169.83
173.93	177.90	181.71	185.31	188.64	191.62	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	17	0.2750000		0.3000000		0.3250000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	71.08	74.97	79.13	83.47	87.93	92.48	97.09	101.75	106.45	111.18	115.92
120.68	125.45	130.22	135.00	139.78	144.55	149.32	154.08	158.82	163.55	168.25	172.91
177.52	182.07	186.53	190.87	195.03	198.92	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	18	0.3250000		0.3500000		0.3750000					
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	67.02	71.60	76.31	81.08	85.91	90.76	95.64	100.54	105.44	110.36	115.28
120.21	125.14	130.07	135.00	139.93	144.86	149.79	154.72	159.64	164.56	169.46	174.36
179.24	184.09	188.92	193.69	198.40	202.98	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SHOALING FOR ENERGY (NOT WAVE AMPLITUDE)

```
          1  5.5000000E-02  5.9999999E-02  6.4999998E-02
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.8299   1.0241   1.2122   1.3900   1.5500   1.6978   1.8306   1.9488   2.0506
2.1374   2.2082
   2.2650   2.3043   2.3256   2.3348   2.3256   2.3043   2.2650   2.2082   2.1374   2.0506
1.9488   1.8306
   1.6978   1.5500   1.3900   1.2122   1.0241   0.8299   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          2  6.4999998E-02  7.0000000E-02  7.5000003E-02
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.7242   0.8949   1.0547   1.2034   1.3410   1.4665   1.5800   1.6822   1.7689
1.8414   1.9016
   1.9488   1.9825   2.0022   2.0107   2.0022   1.9825   1.9488   1.9016   1.8414   1.7689
1.6822   1.5800
   1.4665   1.3410   1.2034   1.0547   0.8949   0.7242   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          3  7.4999996E-02  7.9999998E-02  8.5000001E-02
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.6178   0.7586   0.8930   1.0181   1.1342   1.2388   1.3340   1.4185   1.4908
1.5525   1.6028
   1.6410   1.6693   1.6848   1.6900   1.6848   1.6693   1.6410   1.6028   1.5525   1.4908
1.4185   1.3340
   1.2388   1.1342   1.0181   0.8930   0.7586   0.6178   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          4  8.5000001E-02  9.0000004E-02  9.5000006E-02
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.5388   0.6610   0.7779   0.8855   0.9841   1.0754   1.1556   1.2277   1.2882
1.3410   1.3830
   1.4161   1.4400   1.4520   1.4568   1.4520   1.4400   1.4161   1.3830   1.3410   1.2882
1.2277   1.1556
   1.0754   0.9841   0.8855   0.7779   0.6610   0.5388   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          5  9.4999999E-02  0.1000000      0.1050000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.4830   0.5929   0.6956   0.7903   0.8780   0.9565   1.0282   1.0899   1.1428
1.1859   1.2232
   1.2522   1.2701   1.2837   1.2860   1.2837   1.2701   1.2522   1.2232   1.1859   1.1428
1.0899   1.0282
   0.9565   0.8780   0.7903   0.6956   0.5929   0.4830   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          6  0.1050000      0.1100000      0.1150000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
```

```
   0.0000    0.4462    0.5461    0.6400    0.7276    0.8064    0.8761    0.9390    0.9940    1.0404
1.0795    1.1109
   1.1364    1.1535    1.1642    1.1686    1.1642    1.1535    1.1364    1.1109    1.0795    1.0404
0.9940    0.9390
   0.8761    0.8064    0.7276    0.6400    0.5461    0.4462    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
          7  0.1150000       0.1200000       0.1250000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.4225    0.5170    0.6053    0.6839    0.7569    0.8226    0.8798    0.9293    0.9702
1.0060    1.0343
   1.0547    1.0712    1.0795    1.0837    1.0795    1.0712    1.0547    1.0343    1.0060    0.9702
0.9293    0.8798
   0.8226    0.7569    0.6839    0.6053    0.5170    0.4225    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
          8  0.1250000       0.1300000       0.1350000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.4083    0.4984    0.5806    0.6561    0.7242    0.7832    0.8372    0.8817    0.9197
0.9526    0.9781
   0.9960    1.0100    1.0181    1.0221    1.0181    1.0100    0.9960    0.9781    0.9526    0.9197
0.8817    0.8372
   0.7832    0.7242    0.6561    0.5806    0.4984    0.4083    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
          9  0.1350000       0.1400000       0.1450000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.3994    0.4858    0.5655    0.6368    0.7006    0.7569    0.8046    0.8464    0.8817
0.9101    0.9332
   0.9526    0.9643    0.9722    0.9742    0.9722    0.9643    0.9526    0.9332    0.9101    0.8817
0.8464    0.8046
   0.7569    0.7006    0.6368    0.5655    0.4858    0.3994    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
         10  0.1450000       0.1500000       0.1550000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.3944    0.4789    0.5550    0.6241    0.6839    0.7379    0.7832    0.8208    0.8538
0.8798    0.9006
   0.9158    0.9274    0.9332    0.9370    0.9332    0.9274    0.9158    0.9006    0.8798    0.8538
0.8208    0.7832
   0.7379    0.6839    0.6241    0.5550    0.4789    0.3944    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
         11  0.1550000       0.1600000       0.1650000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.3931    0.4761    0.5506    0.6162    0.6740    0.7225    0.7656    0.8010    0.8299
0.8556    0.8742
   0.8874    0.8987    0.9044    0.9063    0.9044    0.8987    0.8874    0.8742    0.8556    0.8299
0.8010    0.7656
```

```
   0.7225   0.6740   0.6162   0.5506   0.4761   0.3931   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          12  0.1650000       0.1700000       0.1750000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.3956   0.4775   0.5491   0.6131   0.6675   0.7140   0.7534   0.7868   0.8136
0.8354   0.8538
   0.8668   0.8761   0.8817   0.8836   0.8817   0.8761   0.8668   0.8538   0.8354   0.8136
0.7868   0.7534
   0.7140   0.6675   0.6131   0.5491   0.4775   0.3956   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          13  0.1750000       0.1800000       0.1850000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.4007   0.4816   0.5520   0.6131   0.6659   0.7106   0.7465   0.7779   0.8028
0.8226   0.8391
   0.8501   0.8575   0.8630   0.8649   0.8630   0.8575   0.8501   0.8391   0.8226   0.8028
0.7779   0.7465
   0.7106   0.6659   0.6131   0.5520   0.4816   0.4007   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          14  0.1850000       0.1900000       0.1950000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.4096   0.4900   0.5595   0.6178   0.6675   0.7090   0.7430   0.7726   0.7957
0.8136   0.8281
   0.8372   0.8446   0.8501   0.8519   0.8501   0.8446   0.8372   0.8281   0.8136   0.7957
0.7726   0.7430
   0.7090   0.6675   0.6178   0.5595   0.4900   0.4096   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          15  0.1950000       0.2000000       0.2250000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.4212   0.5013   0.5685   0.6257   0.6724   0.7123   0.7448   0.7709   0.7903
0.8082   0.8208
   0.8299   0.8372   0.8409   0.8409   0.8409   0.8372   0.8299   0.8208   0.8082   0.7903
0.7709   0.7448
   0.7123   0.6724   0.6257   0.5685   0.5013   0.4212   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
          16  0.2250000       0.2500000       0.2750000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.5242   0.6006   0.6593   0.7056   0.7396   0.7656   0.7868   0.8028   0.8154
0.8245   0.8317
   0.8372   0.8409   0.8427   0.8427   0.8427   0.8409   0.8372   0.8317   0.8245   0.8154
0.8028   0.7868
   0.7656   0.7396   0.7056   0.6593   0.6006   0.5242   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
```

```
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
          17  0.2750000       0.3000000       0.3250000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.6956    0.7552    0.7957    0.8226    0.8427    0.8575    0.8668    0.8742    0.8798
0.8855    0.8874
   0.8911    0.8911    0.8930    0.8930    0.8930    0.8911    0.8911    0.8874    0.8855    0.8798
0.8742    0.8668
   0.8575    0.8427    0.8226    0.7957    0.7552    0.6956    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
          18  0.3250000       0.3500000       0.3750000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.8668    0.8968    0.9139    0.9254    0.9312    0.9370    0.9409    0.9428    0.9448
0.9467    0.9487
   0.9487    0.9487    0.9487    0.9487    0.9487    0.9487    0.9487    0.9487    0.9467    0.9448
0.9428    0.9409
   0.9370    0.9312    0.9254    0.9139    0.8968    0.8668    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
0.0000    0.0000
```